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LITERATURE FOR 1911 ON THE BEHAVIOR OF LOWER INVERTEBRATES

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Protozoa. Two studies of geotropism in microorganisms appeared during the year 1911, both of them tending to support the view that the effect of gravity is rather a mechanical one, like its effects on lifeless bodies, than that of a stimulus to which the organism responds through the irritability of its protoplasm. Harper (13) placed *Paramecium* in a medium containing very fine particles of iron. When too much iron was ingested by the animals, they sank to the bottom, but when a moderate amount had been taken, there was a tendency to move upward, which Harper ascribes to the fact that the posterior part of the body had had its weight increased by the iron. On the other hand, when finely divided paraffin, a substance lighter than water, was ingested, the opposite tendency was shown. Harper cannot accept the theory of Lyon, that *Paramecium* orients itself by active movements in response to the stimulus of particles within the body, as in a statocyst, for, he says, "It is not easy to see how an animal revolving continually on its axis could react to the localization of an internal stimulus." The evidence which Lyon obtained for his hypothesis by centrifuging the animals, namely, that under such circumstances the anterior end is directed outward and is therefore probably heavier, so that normal negative geotropism, with the anterior end up, must be active, Harper would set aside by explaining the position of the anterior end as due to the animal's compensatory movement against the rotation. Massart's observations that the positions assumed by dead infusoria are not identical with those assumed in reactions to gravity, as should be the

case if the response to gravity is passive, are not mentioned by Harper.

Wager (32) made his observations upon plant forms, such as *Euglena viridis*, *Chlamydomonas*, *Volvox*, and *Spirillum*, but they apply equally to Protozoa. He was especially concerned with the causes leading these organisms to form peculiar aggregations and networks. These aggregations are not related to the presence or absence of carbon dioxide; they are due rather to the forces of gravity and cohesion, "combined with the friction of the water, which sets up a vertical motion as soon as the *Euglenae* begin to fall." "During the aggregation there is a constant cyclic movement downwards and upwards. The downward movement is a passive one, the *Euglenae* being orientated into a vertical position with their anterior end upwards." This is because the posterior end is heavier; dead *Euglenae* sink in the same position. The upward movement is active, but depends upon this same orientation of the body. "The attraction exerted by gravity is not effective unless the *Euglenae* are present in large numbers. If they are few in number, they are capable of moving in any direction, but always with a tendency to move upwards. The aggregation into networks or groups can only take place when the *Euglenae* are sufficiently crowded together for the downward pull of gravity to be effective."

The only study of the effect of light on the behavior of unicellular organisms that has appeared during the year, that of Desroche (6), is also concerned with plant life. The zoöspores of *Chlamydomonas Steinii* Goros are found to maintain a constant speed of movement unaffected by the light intensity. The effect of light is not kinetic but orienting, the movements being directed towards the light if it is sufficiently intense.

McClendon (17), Uléhla (31), and Mast (19) have made studies of the motor processes in the Protozoa. McClendon attempts to show the relation of protoplasmic movement to the forces in a magnetic field. Uléhla, by means of the paraboloid condenser, has made a minute analysis of the movements of the flagellum in various species of flagellates. He finds that these movements are seldom those of simple rotation; various figures are described which are peculiar to the species. The flagella have a very complex internal structure, and a very rapid rate of movement. The regularity of their beat is not easily disturbed. Their action

is that of oars, not screws. The movements which they describe may be classed under six heads, chiefly dependent on the form and flexibility of the flagella.

Mast's (19) description of the movements of *Lacrymaria* is known to the readers of this journal. Its most significant content is perhaps the assertion of the random and unoriented character of the movements. The direction of locomotion is regulated by the movements of the head, which seem to be wholly dependent on internal factors. The only evidence of orientation is that "stimulation of the anterior end may not only cause contraction of the neck but also backward movement of the entire organism, while stimulation of the posterior end usually causes forward movement."

The paper by Day and Bentley (5) on learning in *Paramecium* also appeared in this journal, and therefore needs but brief notice. The method was practically the same as that used by Stevenson Smith, although it was independently developed by Day and Bentley; it consisted in placing an animal in a capillary tube too narrow for it to turn in by the ordinary method of darting backward and turning through an acute angle. A record was kept of the number of efforts it made by this method in successive experiments, before it varied the method and escaped by bending its anterior end. The number of unsuccessful movements and the time occupied by them was reduced in successive trials, showing learning. Precautions were taken against the effects of a chemical change in the medium such as the accumulation of carbon dioxide.

The articles by Jennings (15) and Woodruff (33) are concerned rather with general physiological processes than with behavior. Jennings, however, describes with some minuteness the process of conjugation in *Paramecium*. The first contact is at the anterior tips, which interlock. The period of "fitting" is one of great and varied activity; there are bendings and contractions, as if the animals were making efforts to bring the mouths together. If they do not fit properly they separate, and thus "assortative mating" occurs. Woodruff notes that if a normal medium is supplied *Paramecium caudatum* can reproduce indefinitely without conjugation or artificial stimulation.

Coelenterates. Schmid (30) finds that in darkness, *Cereactis aurantiaca* withdraws its tentacles and stretches out its body.

When full daylight falls suddenly upon it, the body contracts and the tentacles expand and cover it. In dim light it seeks the lightest region. Yellow and red affect the unfolding differently from green and blue. *Actinia sulcata* drops its tentacles in darkness "as if sleeping."

Echinoderms. The paper by Cowles (3) is chiefly concerned with the reactions to light and shadow of isolated pedicellariae of the sea-urchin *Toxopneustes variegatus*. Von Uexküll has a theory that the reaction of the spines to shadows is due to the release of energy from certain "Tonus" centers in the radial nerve, energy having been stored in these centers by the action of light and being set free when the light is withdrawn. He found that the reaction to shadows did not occur when the connection with the radial nerve was broken. Cowles has observed that in the case of the pedicellariae, however, response to shadowing will take place when they are disconnected from the radial nerve. He concludes that their Tonus centers must lie in the tissue of the pedicellariae themselves.

Annelids. *Allolobophora foetida*'s power of discriminating a wet from a dry surface has been investigated by Parker and Parshley (21). A worm that is creeping over a surface of wet filter paper will, when it comes to a dry spot, after moving over it for a short distance "varying from a few segments to half its length," stop, move its head from side to side, withdraw into the moist area, and take a new direction. When worms were forced to creep backwards into a dry area, they did not show any tendency to check their movements. The authors omit to note that this in itself would not be good evidence as to the part of the body which is especially sensitive to dryness, for the worms might have been so occupied with escaping from the stimulation of the head, which was forcing the backward movements, as to be indifferent to dryness. Individuals with the prostomium removed or anesthetized, however, manifested a similar indifference to dryness and it is concluded that the prostomium is the organ which responds to dryness as a stimulus. This stimulus probably acts through the extraction of water from the peripheral protoplasm of the worm, concentrating and partially coagulating the body materials in the prostomium.

Molluscs. Parker (20) finds that certain snails move by a continuous or arrhythmic movement of the foot, instead of by means of rhythmic waves of pedal contraction, as is the case with most species. The foot is an organ of attachment in snails either by means of the mucus it secretes, or by suction, or in both ways. A wave in the foot is a portion that is lifted from the support and is moved forward; this local forward movement takes place in successive sections of the foot until the whole has been moved.

A careful study of the movements of heteropod and pteropod molluscs has been made by Polimanti (26). He has also investigated the functions of the ganglia and statocysts in these animals. Lesion of the cerebral ganglia produces heightened reflex irritability. The pedal ganglion is the organ of locomotion, and when it is destroyed, motor coördination is lost. Destruction of one statocyst produces rotation towards the uninjured side; destruction of both results in complete disorientation. This is more marked if the eyes are also extirpated. Ordinary sound stimuli have no effect on movement, but jarring the water so as to produce tactile stimulation does have an effect.

Yung's papers (34,35) report his conclusion that the snail *Helix pomatia*, although it has well developed eyes, is totally blind and not even dermatoptic. The individuals he tested were perfectly indifferent to shade or bright sunlight on the floor of a room, and to dark or light compartments of a box; they did not respond to sudden variations of light intensity such as the turning on of an electric lamp or the flashing of a light by means of a mirror; and they gave no evidence of being able to avoid obstacles by vision. A pin-head was repeatedly approached to the eye and then struck against it: the tentacle bearing the eye was withdrawn at the touch, but never, in spite of repeated experience, before it. Snails with the eyes removed behaved in all these respects precisely like normal individuals. It is certainly interesting to find that an organ apparently in perfectly good condition can be without function. The danger of arguing from purely morphological evidence is well illustrated.

Piéron (24, 25) makes use of the light reactions of a common snail (*limnée*) to investigate the laws of memory. In the first of these two papers he undertakes to find out how rapidly the effects of adaptation to a repeated visual stimulus die away

with time. The first step is to determine how many times a shadow of a definite duration, the light being otherwise kept at a given constant intensity, must be made at a fixed rate before the snail will cease to respond by drawing in its tentacles. When this number has been found, the experiment is repeated after a given interval, and if the interval is not too long, the effects of the previous experience will be shown in the fact that not so many repetitions of the shadow are now required to produce cessation of the reaction. The longer the interval, the smaller will be the amount of the saving in repetitions thus brought about. By determining the amount of saving for different intervals, Piéron establishes the formula m

$$k (\log t)^a$$

(the mnemonic trace) = $\frac{k (\log t)^a}{t^\beta}$, where k , a , and β are constants and t is the interval of time elapsing since the first experience. Piéron thinks that the formula thus found is truer even for human memory than that of Ebbinghaus, which is

$$m = \frac{k}{(\log t)^a}, \text{ and supports this statement by some experiments on the human subject.}$$

In his second paper (25), his purpose is to find out what interval between successive shadowings will most quickly bring about cessation of reaction. He finds that for the fresh-water snail the optimum interval is from ten to twenty seconds, and that for *Littorina* it is as long as one minute. In man, as has been indicated by the experiments of Jost and others, it may be as long as twenty-four hours. Whether the process of becoming adapted to repeated stimulation really has anything in common with the processes of establishing associations in the human cortex remains a question.

Dawson's monograph on the biology of *Physa* (4) considers in its first section the subject of habitat. The following conditions are enumerated as those of an optimum environment: "shallow water, minimum amount of shade, few or no enemies, minimum amount of debris, protection from waves and currents, moderate amount of water weeds, and well aerated water." The second section is devoted to mucus and the spinning of mucus threads. The common practice among water snails is,

on leaving the substrate on which they have been crawling, to float up through the water, drawing behind them a thread of mucus, on which, after the lung has been filled with air, they descend. The spinning process in *Physa* is affected by the food supply, by general activity, and by habitat. Its adaptive aspect is not clearly made out. It cannot be related to need of air, for if the snail's lung is not already full of air it will not be light enough to ascend through the water, but must crawl on a solid. In Section III food taking is discussed. Low temperature decreases the snail's eagerness for food. Odorous foods are more quickly found than odorless ones. The snail can sense food at not over one centimeter away. "All parts of the head and the first few mms. of the ventral surface of the foot were found to be sensitive to food." Negative responses were obtained to hydrochloric acid, onion juice, pieplant, and the juice of a walnut husk. When mechanical and chemical stimulation are combined the former is first effective; a snail which in rapid crawling comes in contact with food gives the negative response first and then the feeding response. A well-fed snail has its responses to the neighborhood of food decidedly weakened, while a fasting snail will give the food reaction to mere mechanical stimuli and even to chemical stimuli which ordinarily produce a negative reaction. Part IV, on respiration, contains nothing which calls for report here. The last section is entitled, "Some Psychic Phenomena of *Physa*." A snail's reaction to stimulation is much influenced by its previous experience, of being handled, for example. A snail dropped into an aquarium where it had been previously kept crawled at once to the surface as though traversing a familiar path, while snails freshly taken from the pond wandered about aimlessly on being dropped into the same aquarium. On travelling several times to the top of the water in an aquarium, the snails showed less aimless wandering and exploratory tapping with the siphon. The following experiment indicates that *Physa* remembers the location of the surface film. The vessel containing the snails was covered with a glass plate resting directly on the water. The snails came up for air and tapped their siphons on the glass, behaving as they usually do at the surface film. Various other evidences of the influence of past experience are noted.

Crustacea. Most of the work done on animals of this group concerns, in one way or another, their reactions to light. McGinnis (18) has observed the behavior of the fairy shrimp, *Branchipus serratus*, under stimulation by light; heat, and gravity. The animal is positively phototactic under lights from twelve to two hundred and eighty candle power. After exposure to darkness for a period of from twelve hours to six weeks the shrimps are still positive. Light has also a kinetic effect, increasing with its intensity; that is, it stimulates to activity. When *Branchipus* reacts to light its ventral side is turned towards the source, and its long axis is at right angles to the direction of the rays. The eyes appear to be the only organs for the reception of light as a stimulus. *Branchipus* is positive to temperatures from 14 to 17 degrees C., and avoids temperatures above and below these limits. It is positively geotropic in light and negatively geotropic in darkness; light therefore must have besides its directive and kinetic effects a third influence whereby geotropism is reversed. It is possible that darkness rather than light may furnish the stimulus to this reversal.

The temperature sensibility of Zoea larvae has been investigated by Schmid (29), who notes a distinct reaction of jumping back given by the animals when they reach the boundary between water at ordinary temperature and water at a temperature too high for them.

The effect of chemicals on the reactions to light made by crustacea has been the subject of some experiments by Bohn and Drzewina. Drzewina (8) finds that hydrocyanic acid is a desensibilisator to light; she notes also that copepods of the plankton are much more sensitive to its influence than those of the surface layers of water, where much decomposition is always going on. Bohn, working with larval lobsters, finds that both acids and alkalis are sensibilisators. The effect lasts longer with alkalis, but is weaker. With acids, the maximum effect is shown at the end of a few minutes, and the effects vanish after a few hours. With alkalis, the maximum effect occurs only after several hours, but the influence may persist for several days. The two experimenters working in collaboration (9) found that potassium cyanide reverses positive phototropism in certain crustacea and "desensibilises" to tactile stimuli more rapidly than to light.

Esterly (10) has reported records of the daily depth migrations of *Calanus finmarchicus*. During June and July the greatest assemblage at the surface of the water is between seven and eight P. M. The migration begins before midnight. Its cause, Esterly thinks, is light, but not directly; rather by the effect of light upon geotropism.

Doubt is cast on the very existence of such depth migrations by Franz in the second of the two papers by him on our list (12). He is strongly inclined to think that biologists have been led to suppose that daily migrations occur from the surface of the water to the deeper regions and *vice versa*, by the simple fact that in daylight the animals can see and avoid the collecting net, whereas at night they cannot. It scarcely seems probable that so obvious a source of error as this should have been overlooked. Franz believes that phototropic reactions are never shown under the influence of light alone, but only when unfavorable life conditions exist, so that the flight-reflex occurs. Whether the phototaxis is positive or negative depends on whether the animal in its ordinary surroundings can escape into the open or into covering. In the first of the two papers on our list (11), he shows that various animals, including copepods and *Daphnia*, display phototropism only when confined in a small space. In the second paper he makes a similar observation on *Palaemon serratus* and on some larval crustacea and worms. Marine copepods show a varying response to light, some individuals being positive, others negative, and the tropism of a given individual is reversed at times. Franz thinks that on being introduced into the observation vessel, most of them try to escape by swimming towards the light, and that when this procedure is not successful, they become negative. Animals which may display either negative or positive phototropism are those which under normal life conditions can escape in either way. Very young larvae are predominantly positive, owing to their need to seek light. Phototropism being thus dependent on the flight-reflex, "there is scarcely any analogy between phototaxis in animals and phototropism in plants." A final section of this paper considers the peculiar behavior of *Hemimysis*, which oscillates back and forth in the water in which it is confined, its excursions being from ten to twelve centimeters long. Franz thinks that the turning occurs when the animal gets

into a region either too light or too dark for its existing state of adaptation; the reflexes cease when the light is diffused. Foul water makes all the individuals positive; movement from darkness into the open would be their flight-reflex under normal conditions.

Hess also, as is well known, opposes the identification of phototropism in animals and in plants, although on other grounds. He here (41) reports, besides experiments on fish and birds, some tests made with the branchiopod *Artemia salina*, which is normally strongly negative in its response to light. He put a number of individuals into a cubical vessel placed at the middle of a black tunnel; at either end of the tunnel was a light. The sensitiveness of the animals to differences in the intensity of these two lights was measured by keeping one of them at a constant distance of thirty centimeters, and moving the other one. No difference in the behavior of the Artemias was observed until the second light was moved either further off than thirty-two centimeters or nearer than twenty-nine centimeters. When a red light and a blue light were used, a very light red and a very dark blue proved to be equal in their effect on the light reactions of the animals, and corresponding results were obtained by equating red and blue with white light. Another method was used to investigate the reactions of *Artemia* to colored light. The cubical vessel containing the animals was divided by glass partitions into four parallel compartments, and a spectrum thrown through the side wall in such a way that one compartment was illuminated chiefly by red light, one by orange and yellow, a third by yellow-green and green, and the fourth by blue and violet. The Artemias all crowded against the opposite wall of the vessel. A long, cylindrical incandescent tube was placed parallel to this other side, and the intensity was measured of its light when it was able to overcome the negative effect of the colored light in each compartment. The brightness values of the colors thus measured indicated that they were the same as those for a color-blind human being. Hess believes that he has found the brightness values of colors to the vertebrate eye, on the other hand, to be identical with those for the normal human eye, and argues on this ground against Loeb's position that the effect of light on animals and on plants is

essentially the same. His results for the vertebrates do not agree, however, with those of the American investigators.

Pearse (23), by means of careful experiments, described in this journal, on the crayfish, spider-crab, caddis-fly larva, and crab-spider, comes to the conclusion, in opposition to Minkiewicz, that these arthropods are unable to select an environment which matches their own color.

Polimanti (28) describes a case where a crab, *Dromia vulgaris*, had attached to its back a sponge, *Suberites domuncula*. In this case of symbiosis the initiative must be taken by the crab, and Polimanti believes that associative memory plays a certain part in the crab's behavior.

In his study of the mating behavior of certain crabs, Chidester (2) concludes that there is no evidence that sexual selection is involved. The males recognize the females by touch. Males attempted to mate with other males and with fertilized females, but never with individuals of other species. "Opportuneness of proximity" is the most important factor in bringing about mating.

Three papers of a more general character may be briefly mentioned. Doflein (7) asserts his belief in the distinctness of the organs of taste and smell even in water-dwelling animals. The former test substances entering the alimentary canal; the latter test the environment in general. In land crabs the small antennae have an olfactory function, which is doubtless the same in water-dwelling forms.

Polimanti (26) describes observations made in the aquarium at Naples on the periods of activity and repose in a great variety of marine animals, including sea-anemones, hydroids, siphonophores, ctenophores, echinoderms, annelids, crustacea, molluscs, tunicates, cartilaginous and bony fishes, and turtles. In general, he found that periods of great activity in all these animals are followed by short intervals of lessened activity; the repose, however, is never really complete. Temperature and light are the chief regulators of activity and rest. The greatest activity is nocturnal. The comparatively constant temperature of the sea economizes the energies of marine animals and permits their high activity. An abnormal degree of activity often occurs before death.

Lund (16) contributes a brief report of observations on the reactions to light of animals which themselves produce light. Some of the behavior which he studied was that of insects, but among the lower invertebrates he noticed that certain luminous ostracods respond to the stimulus of light by emitting a luminous secretion, and that some of the Cirratulidae and Syllidae are attracted to a source of light and to each other when emitting light. Thus in these forms the self-produced light coöperates with a positive phototropism to bring about reproduction.

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LITERATURE FOR 1911 ON THE BEHAVIOR OF SPIDERS AND INSECTS OTHER THAN ANTS

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TROPISMS

1. *Thigmotropism*. H. H. P. and H. C. Severin (53) have obtained experimental evidence that certain water bugs are positively thigmotactic. In an aquarium containing water one inch deep, they placed thirty-five specimens of *Belostoma flumineum* Say, and scattered on the top of the water several large flat corks. In a few hours thirty-two of the insects were resting against the lower sides of the corks. Frequently, at the surface of the water and at the bottom of the aquarium, two or more *Belostomas* were found clinging together. This the authors consider a positive thigmotactic response. *Belostoma americanum*, *Benacus griseus*, *Nepa apiculata*, *Ranatra americana*, and *Ranatra kirkaldyi* react in the same manner.

2. *Phototropism*. The opinion has been hitherto held that the Hepialidae fly only at twilight. J. McDunnough (36), however, last summer observed *H. hyperboreus* flying on the northern slope of Mt. Hood between half-past two and three in the afternoon, in the sunlight, on three successive days. He thinks that the species may have changed its habits on account of the coldness of the evenings in that latitude.

According to E. A. Andrews (9) termites, although blind, respond to light by collecting where the intensity is least. Andrews does not call this a tropism, but Bohn would.

If the hand is passed over a jar containing larval mosquitoes, all of the insects swim downwards. In order to classify this behavior, S. J. Holmes (30) has performed a series of experiments. A glass jar containing *Culex territans* and *Culex pipiens* was arranged in a window in such a position that the light fell upon it obliquely. Whenever a dark object was passed over the jar, the larvae swam downwards and towards the side that was away from the light. When conducted in a dark room, with the light impinging on only one side of the aquarium, the ex-

periment yielded the same result. Hence Holmes logically concludes that the direction of the rays of light is a factor in determining the direction of the movements. Whenever a shadow was cast upon a larval mosquito, even when the shadow was cast by an object beneath the aquarium, the larva always moved downwards and away from the light. When shadows were cast upon larvae resting on the bottom of the jar, commotion was produced, but no definitely directed movements. A series of experiments conducted with larvae of all ages demonstrated great variation in their phototactic response, and that the variations are not due to age. Some were indifferent, some moved towards the light, and some moved away from the light; but all responded to shadows in the manner mentioned above. Since the larvae always dart downwards and away from the light, no matter from what direction the shadow comes, Holmes concludes that this characteristic retreat of the larvae is not a tropism, but a specific response to shadows. Evidently this is an example of what Bohn would call differential sensibility, and what less conservative writers would term an exhibition of fear.

According to the same investigator (30), the adult mosquitoes display a peculiar combination of responses to light, but are more apt to settle on dark than on light objects; and during the day they seek the shade even when it is neither hot nor dry. At night they sometimes fly towards the light. The adults of some species show marked positive phototaxis. Eating a full meal does not alter the phototactic response.

C. H. Turner (58) has conducted a series of experiments to test the response of certain parasitic bees of the family Stelidae to light. The bees were confined in a rectangular wire cage sixteen inches high, twelve inches long and twelve wide. To keep them in a physiologically normal condition, they were supplied with honey and with water. Record was kept of their behavior under the following conditions: when all sides of the cage were exposed to diffuse daylight, when one side of the cage was exposed to the oblique rays of direct sunlight, when the top and two sides of the cage were exposed to such rays, when such rays were admitted only through the upper or lower half of one side, when a narrow beam of electric light was passed through the cage in such a manner as not to impinge upon any of the inmates, etc. The experiments demonstrated that, when

confined within a small cage, the bees of the species studied make certain movements that finally bring them in contact with that side of the cage through which the direct rays of the sun are entering. That this effect is produced, not by a bright patch, but by the direction of the rays of light, is evidenced by the fact that a strong beam of light may be projected through the cage without arousing any response from bees upon which the light does not impinge. A shadow cast upon a bee basking in the sun usually causes it to move. The aroused bee may go to a bright spot on the cage, or to the bottom of the cage, or to the mud cell that is its home. Frequently the bees crossed the rays of light at every possible angle and examined first one side and then another of the cage, as though seeking an exit. These experiments caused Turner to conclude: "These bees are endowed with a pronounced tendency to move in the direction of the rays of light and towards their source; but they do not invariably so react; frequently they make unpredictable responses. Light, heat, sexual restlessness and, perhaps, other factors arouse in these bees an impulse to roam from home. Coupled with this impulse to roam, there is an instinctive tendency to seek freedom in the direction of the rays of light. When following this instinctive tendency fails to bring freedom, the bee tries other methods. In this endeavor many bees make haphazard flights in all possible directions; while others, in a more systematic manner, hover repeatedly before the sides of the enclosure. If such behavior can be called a tropism, then these bees are positively phototactic. Without predicating curiosity or logical thinking to these bees, and granting that the behavior of a boy is more flexible, it seems to the present writer that the reaction of these bees towards light resembles more the response of a small boy to the music of a brass band than it does the turning of a magnetic needle towards the pole."

SENSATIONS

1. *Auditory Sensations.* E. A. Andrews (9) has conducted some experiments which he thinks indicate that termites respond to concussions of air as such. A nest of termites was suspended from the ceiling by means of a copper wire. In a pan of water supported by a concrete wall extending from the ground, he placed an artificial stone weighing sixteen pounds. The nest

communicated with this moist stone by means of a long stick of wood. Thousands of individuals from the nest frequented this stone. The noise of thunder or of the blasting of rocks would send the insects hurrying to the nest. Even the clapping of hands, which was probably too slight to jar the stone, would produce the same effect; but the blowing of horns at various pitches produced no effect. Andrews does not claim that this is a case of audition; he simply holds that the termites seem to respond to certain concussions of the air.

2. *Sense of Smell.* Andrews (9) thinks that many of the activities of termites are influenced by stimuli which produce something akin to the sense of smell. (See Andrews under "Homing").

3. *Vision.* During the year two experimenters, Allard (8) and Turner (57) have conducted experiments on the color vision of insects. The methods and the materials used were different, yet each investigator is convinced that the bees possess true color vision.

Allard (8) worked with various bees (*Melissodes bimaculata*, *Bombus*, *Entecnia*, *Apus*). He used the following objects as stimuli: normal cotton blossoms, and blossoms whose petals had been removed; cotton blossom petals pinned to the stem, a single petal thus pinned on, cloth petals arranged to resemble a cotton blossom, cloth petals so arranged and covered with real cotton petals, and, finally, cotton leaves wrapped around petals to imitate a cotton bud. These objects were arranged in groups of threes on a cotton field, the grouping being either in a triangle or in a straight line. The results of Allard's experiments lead him to the following conclusions: bees are guided to cotton blossoms by sight, after they have entered the cotton field; the inspecting process, however, is not dependent for its initiation on the size and general appearance of the blossoms; if a blossom is visible only to bees directly above it, it is seldom visited; artificial objects are rarely inspected, probably because the bees observe their differences in color and texture from the natural objects; a blossom is inspected much oftener than it is entered; it is hard to determine the relative importance of sight and smell in determining close inspection of a blossom, although sight is instrumental in bringing about the first approach; bees are much influenced by conspicuousness and coloration in per-

ceiving cotton blossoms; associative memory of a kind is involved, since young bees do not appear to work to so much advantage as experienced bees. Experience is also evident in the fact that bees which have been collecting honey from American cotton blossoms, which have extra-floral nectaries, visit similar structures on blossoms of the Asiatic variety, which have no honey in them; but soon depart. The cotton field itself, Allard thinks, is found by a kind of odoriferous cloud hanging over it. He does not bring any experimental evidence to the support of this statement.

C. H. Turner (57), in experimenting on pattern vision in the honey bee, made use of pasteboard boxes like those employed in his experiments of last year on color vision in the same insect. He constructed artifacts showing seven different color patterns. Bees which had been trained to gather honey from one pattern were tested to see if they could choose this pattern from one or more of the others. In some cases the artifact of the pattern to be chosen contained honey, while the rest had none; in other cases there was honey on some of the artifacts of all patterns, and in still other cases there was no honey on any of the artifacts. Five hundred and eight correct selections out of 518 were made, indicating that color patterns are perceived by bees. Since they can distinguish both color and pattern, no evidence can be drawn from the visual powers of bees against the hypothesis that colors and patterns in flowers are adapted to secure the visits of insects.

The experiments discussed above do not demonstrate that colors appear to insects just as they appear to us; that question cannot be determined experimentally; but, it seems to me, they do prove that these insects discriminate between colors. Furthermore, these experiments do not predicate to insects color preference. Color discrimination is one thing and color preference another. Recently A. S. Pearse (43) has given some attention to the matter of the color preferences of insects. His experiments were planned to test the ability of the larval caddisflies (*Neuronia postica* Walker) and of the crab spider (*Misumena aleatoria* (Hentz) Emerton) to select from a variety of colors those that match their environment. The caddis-fly larvae were placed in small rectangular aquaria and each aquarium

placed in a tightly fitting box, the inside of which was painted a certain color. (This box was called a color box). A piece of card-board the same color as the inside of the color box was arranged above the aquarium in such a manner as to reflect that color into the aquarium. The colors used were black, white, yellow, green, blue. He then cut a number of one by fifteen millimeter paper slips that were so colored as to match the inside of the color boxes. Four slips of each color were placed in each jar. In selecting slips to build into their cases, the larvae did not display any color preference. At the beginning of his experiments on the spiders, Pearse tested the spiders' reactions towards a beam of white light and demonstrated that the spiders do not exhibit any form of phototropism. Other preliminary experiments demonstrated that although these spiders occasionally change in color until they resemble the environment, yet the change takes place too slowly to be of any protective value. The real tests were of two kinds: experiments with color-boxes and experiments with flowers. In nature some specimens of the species examined are white and others are yellow. One vertical half of each color box was painted white and the other half yellow. By means of a small opening, the spiders were passed, through a narrow tube, into the box at the place where the two colors met, and a record kept of the side into which the spider went. In the flower experiments, a spider was suspended, by means of a fine thread, half way between a yellow and a white blossom, and a record made of which way the spider attempted to go. Neither type of experiment gave any evidence that the spiders exhibited color preference. Pearse experimented with crustacea as well as insects and, as a result of all his experiments, he concludes: "It cannot at present be affirmed that any protectively colored arthropod reacts towards colored objects or backgrounds in such a way that it can be said to have even an instinctive knowledge that it is protectively colored; *i.e.*, arthropods do not choose the most favorable color environment on account of color." The experiments warrant the conclusion; but it must be remembered that proving that certain insects do not exhibit color preference does not disprove that insects possess color discrimination.

FEELING AND EMOTIONS

It has been found by H. H. P. and H. C. Severin (53) that when an aquarium containing *Belostomas* is suddenly approached, the bugs flee in all directions from their resting places, a performance which is considered by these investigators as indicating fear. *Nepa apiculatum*, *Ranatra americana* and *Ranatra kirkaldyi* show no such signs of fear under similar conditions. At the present stage in the development of the science of animal behavior, it is probably impossible to state what would be considered a conclusive attitudinal indication of fear. A more conservative writer would be inclined to call the behavior of these bugs an example of differential sensibility.

A. D. Hardy (26) thinks he has discovered in the wasp *Diamma bicolor* signs of anger. He bases his conclusion upon the following observation. *Diamma* was dragging a cricket into her burrow when Hardy, with a pair of forceps, held the cricket by the hind legs. After tugging and tugging without accomplishing anything, the wasp suddenly stopped pulling, mounted the cricket, seized its abdomen with her jaws and stung the insect three times. A reviewer would hardly be warranted in asserting that this is not a case of anger; but it does seem that another interpretation is possible. At another place in the article Hardy has described what the wasp does when an insect recovers from the sting and begins to move. In that case the wasp stops tugging, mounts the cricket, seizes its abdomen in her jaws and stings it. A paralyzed cricket would be unable to resist the efforts of the wasp to drag it along. A cricket that had wholly or even partly recovered from the effects of the sting could, by clinging to the surroundings, offer such resistance, and hinder the wasp in the same manner that Hardy did with his forceps. Until it has been proven that the way in which the wasp reacted to the cricket held by Hardy is not its normal manner of reacting to a revived victim struggling to escape, it does not seem necessary to predicate anger in order to explain the behavior described by Hardy.

MATING INSTINCTS

According to J. B. Davey (20) the tsetse fly (*Glossina fusca*) mates on the trunks of trees.

F. Fuchs (22) noticed two males copulating with one female *Cheimatobia brunata*. The next morning both males were dead.

The female laid eggs. He also observed a male *Larentia bilineata* copulating with a female *Acidalia aversata*. Next morning both were dead; no eggs were laid.

Hinds and Turner (29) find that the rice-weevil (*Calandra oryza* L.) may mate within twenty-four hours after emergence, and that it is both polyandrous and polygamous.

E. N. Cory (18) describes in detail the copulation of *Sanninoidea exitiosa* Say. He finds that copulation always occurs on some support, and that a pair remains *in copulo* from 51 to 82 minutes.

A. F. Burgess (15) states that the beetles of the species *Calosoma sycophanta* copulate several times during the summer. Between June 27 and July 26, one pair was observed to copulate thirteen times.

Burgess (15) placed a trap cage containing adult females of the species *Calosoma sycophanta* in the open, half a mile from any trees. No males entered the trap. A trap cage containing female *C. sycophantas* was placed in an open space at least two miles from any males. Males were liberated at distances of one half mile, one mile, etc. No males entered the trap.

C. H. Turner (58) describes in detail the mating of a parasitic bee of the family Stelidae. These bees were noticed to mate in both the sunshine and the shade; but always on a vertical or horizontal support, never on the wing.

That certain syrphid flies hover before flowers for long stretches of time, and that several other species of flies engage in a kind of a dance, in which the heads of all of the flies are directed the same way, has been known for several years. By some people the first phenomenon is considered evidence that these flies possess an aesthetic taste; by entomologists the second is usually considered an anemotropism. A desire to obtain a rational explanation for these two types of behavior caused Pérez (46) to make a careful study of the hovering of one species of fly and of the aerial dances of several. He noticed that *Syrphus le balteatus* Degh. hovers in practically a stationary position before a flower or object for a while and then suddenly darts to one side or to the other. Plateau noticed that the hand can be interposed between the fly and the flower without the fly's giving any indication that it notices the substitution. He also observed that if the hand be moved to right or to the left, forward or

backward, the fly will move in the same sense. By this means Plateau succeeded in inducing a fly to move almost a meter from its original position. This work of Plateau convinced Pérez that it is not the beauty of the flowers that causes the flies to hover before them. Pérez soon noticed that the flies hovering before the flowers were always males, and that the darting sidewise was initiated by the arrival of small insects. Suspecting that the male was lying in wait for a female, he captured a female of the same species and released it near the hovering male. At once the male darted after it. Although the copulation was not observed, Pérez thinks mating occurred. According to Pérez, *Homalomyia manicata* Meig., *Homalomyia la acalaris* F., *Anthomyia pluvialis* L., and *Anthomyia albicincta* Fall. engage in complex dances in which the flies rise and fall in vertical planes. None but males participate in the dances. When a female appears and a male succeeds in reaching her, he abandons the dance. If a number of females are turned loose in the midst of a number of dancing males of *H. maniculata*, in a short while all of the dancers will disappear. *Limnobia chorea* Meig. has a complicated dance in which the male flies move in horizontal rather than vertical planes. Neither *Calliphora erythrocephala* nor *Lucilia caesar* engages in dances. In each of these species the male rests quietly on some support until a female comes within range, and then darts after her. In *Chloria demandata* Fabr. males and females walk about on some isolated surface. When a male approaches a female, he describes circles about her. After circling in one direction for a short time, he turns about and moves in the opposite direction. After this has been repeated several times the flies mate. These experiments caused Pérez to conclude that both the stationary hovering of the Syrphidae and the aerial dances of other flies are means of securing mating. This seems to be the most logical interpretation of this behavior that has been proposed. The hovering of the Syrphidae in one place, the aerial dances of certain flies, the posing of others on surfaces and the sun-dances of certain bees are all brought under the head of what has been termed a "nuptial ambushade." *

* C. H. Turner. The Sun-Dance of Mellissodes. *Psyche*, 1908, 122-124.

NEST-BUILDING AND MATERNAL INSTINCTS

According to Glen Herrick (27), in October and early November the fertilized female of the cabbage aphid lays a large number of eggs on the cabbage. A few eggs are laid on rape, turnips, brussels sprouts and kohlrabi. Usually the eggs are placed in depressions and crevices on the underside of the leaf. These eggs hatch the following spring.

Hinds and Turner (29) state that the rice-weevil deposits its eggs in the kernel of some grain. The eggs hatch in about three days after they are laid.

According to H. H. King (31), the eggs of *Tabanus par* Walker are laid on the under sides of the leaves of water plants. Although in a cluster, each egg is vertical and distinct.

E. N. Cory (18) states that *Sanninoidea exitiosa* Say, when about to oviposit, arches the center of her abdomen upward and points the tip, with its protruding ovipositor, downward. She gently swings the abdomen from side to side, occasionally pausing to touch it to the leaf. Each egg is deposited singly and glued to the leaf by a secretion which is placed on the leaf before the delivery of the egg. Of 455 eggs deposited, 390 were placed on leaves and 65 on the trunk.

According to E. R. Sasser (51), the ash saw-fly (*Tomostethus mullicinctus* Rohwer), in ovipositing, points her head downward and thrusts her ovipositor under the epidermis near the edge of the leaf and, after laying an egg, flies to another leaf and repeats the process. The egg is always inserted near the edge of the leaf and not in the petiole nor in the midrib, as is done by closely related species.

P. J. Parrott (41) confined three species of tree-cricket (*Oecanthus niveus* DeGeer, *O. nigricornis* Walker, *O. quadripunctatus* Beut.) in breeding cages, with growing apples and raspberries. He used ten pairs of *niveus*, six of *nigricornis* and four of *quadripunctatus*. When apples and raspberries were both present, *niveus* always oviposited in apples; when apples were not present it used raspberries. *Nigricornis* and *quadripunctatus* always preferred raspberries; when it had no other alternative, *nigricornis* sometimes laid in applewood. In ovipositing the female gnaws a hole in the bark; then, moving the ovipositor at right angles to her body, she advances, inserts the tip of her ovipositor into the hole, and proceeds to drill a

cavity for the reception of the egg. The drilling is accomplished by thrusting and rotating the ovipositor. After ovipositing, an adhesive substance is discharged, which is kneaded about the egg by the ovipositor. After withdrawing her ovipositor, the cricket reverses her position and completes the process by capping the opening with small pieces of bark, which are held in place by the mucilaginous substance surrounding the egg. The time required for the process varies with the species, and, to a lesser extent, with the individual. In apple-wood one and one-half inches in diameter, *O. niveus* spent seven to sixteen minutes gnawing the hole, twenty-seven to seventy-six minutes drilling with her ovipositor and three to five minutes depositing and disguising the egg. In ovipositing in raspberries, *O. nigricornis* spent five to eleven minutes gnawing the bark, twelve to seventeen minutes boring with her ovipositor and five to seven minutes laying and disguising the egg.

In the summer of 1908, Paul Lozinsky (33) found, in a semi-dark place, a glass tube 147 mm. long and 7.5 mm. in diameter, which contained a nest of *Osmia bicornis* L. The nest consisted of nine full cells and one which had been sealed empty.

The larvae of *Mecistogaster modestus* have been observed by P. P. Calvert (16) living in water between the leaves of epiphytic bromelids. This mode of life Calvert thinks originated in the accidental laying of eggs in the bromelids at a time when the level of the water had been raised by floods. After the plant is again far above the water the association still persists.

E. A. Andrews (9) writes that the chief areas of termite activities are the nest, the arcades and the feeding grounds. The arcades are closed archways that extend from the nest for a distance of about fifty feet. Through these arcades the termites move to and fro in groups. No description is furnished of the construction of the nest; but a detailed description is given of the method of constructing and repairing the arcades. There are four steps in the construction of an arcade: establishing the path; adding to the path, at irregular intervals, sections of two parallel walls; filling in the gaps in these walls; adding a roof to the walls. The wall is constructed of vegetable matter that is cemented with anal discharges. A female adds a mouthful of material; then, turning, cements and glazes it with a fluid which she squirts from her anus. In some cases

coral sand is added to the outside. Often there are chinks in the walls. Whenever the arcade warps from the support, the termites construct a new floor. Any punctures that occur in the wall are repaired, from the inside, by anal secretion added drop by drop.

C. H. Turner (59) has noticed an American *Ammophila* stock its nest with subterranean caterpillars. That European *Ammophilas* stock their nests with subterranean caterpillars has long been known; but it is thought that this is the first time such a habit has been recorded of any of our American species.

E. Roubaud (49) has had the unusual opportunity of observing, within a single genus, various stages in the evolution of an instinct. The *Synagris* are a genus of Eumenidae living in the Congo region. *S. calida* L. constructs a nest of several mud cells, stocks the cells with caterpillars, lays an egg in each, seals the cells and takes no further notice of them. *S. sicchiana* Sauss. lays an egg in each of several mud cells, places in each enough caterpillars to last the larva a little more than one day, and replenishes the store daily. *S. cornuta* L., when she has completed one cell, lays an egg in it; but does not stock it with caterpillars. When the larva has hatched, it is fed by the female wasp until it is a full grown larva. Then the mother seals the cell and proceeds to construct another.

FIGHTING AND FOOD-PROCURING INSTINCTS

According to the Severins (53), *Belostoma* is carnivorous. It captures its prey with its front legs and holds it with them until the juices have been sucked from the body. It feeds on back-swimmers, water-boatmen, larval and nymphal dragonflies, snails, may-flies, and larvae and weaker specimens of its own kind. *Nepa* also is carnivorous, but it never runs nor swims after its prey.

C. C. Gowdey (1) observed two specimens of *Bembex tricolor* Dahl. carrying off an example of *Tabanus secedens* Walk.

According to R. Boyce (14), the natural food of *Stegomyia fasciata* is minute algae. He finds that this mosquito bites by day as well as by night.

H. M. Bower (13), while studying the early stages of *Lycaena lygdamus* Doubleday, noted several cases of cannibalism.

N. Banks (10) noticed a phorid fly, *Aphiochoeta xantiippi* Banks, attacking a myriapod (*Parajulus* sp.?).

F. Knab (32) discovers that *Megarhinus*, a genus of mosquitoes, does not suck blood, but feeds upon fruit. And he thinks that all authors who believe otherwise base their opinion upon insufficient evidence. Although all parts of the proboscis of the blood-sucking forms are present in the proboscis of this form, yet the sheath or labium is strongly chitinized and rigid, which is not the case in the blood-suckers. These forms have been observed feeding upon honey.

Chas. H. Davidson (21) describes a case of a fish (*Lucius americanus* Gmelin), which was nearly three and five-eighths inches long, being captured and fed upon by a large bug (*Lethocerus* (*Belostoma*) *americanus* Leidy).

F. A. McDermott (35) noticed a larval half-winged bug attack a tent-caterpillar. The bug thrust its beak at the caterpillar several times before it succeeded in piercing the skin. At each thrust the caterpillar moved its head towards the bug and the bug dodged. When once the skin of the back had been pierced, the caterpillar offered no further resistance.

W. C. Coker (17) has conducted some simple but conclusive experiments to test the ability of the house-fly to do without water and without food. He placed a certain number of flies in dry tumblers and an equal number in tumblers kept moist by damp sphagnum moss. At the end of forty-eight hours all of the flies in the dry tumblers were dead; those in the moist chambers were living, but not so active as at first. At the end of seventy-two hours all of the flies were either dead or too feeble to walk. Two weeks later this experiment was repeated with practically the same result. Evidently, under normal conditions, the flies investigated cannot live more than about two days without water and not more than about four days without food.

E. A. Andrews (9) notes that the termites feed chiefly upon wood. He did not find any true "fungus gardens." In their stead he found dry masses of stored-up food, which Andrews thinks may represent the primitive forms from which the true culture gardens of other climates have been developed.

In order to see whether the sarcophid flies are parasites or scavengers, T. L. Patterson (42) conducted a series of experiments.

From an area with a radius of ten miles, 3,273 pupae and prepupal larvae were collected and placed in pasteboard boxes 8x5x4 inches. These boxes were examined almost daily. No sarcophagids were raised from any of the active pupae or prepupal larvae; but, from the dead and inactive pupae many were hatched. Live prepupal larvae and active sarcophid flies were confined to cages for several days; after which the larvae were transferred to jelly glasses with mosquito-netting tops. In no case did a sarcophid develop. Live maggots of these flies were placed on active pupae and prepupal larvae, but they did not enter the bodies of any; nor would adult flies oviposit upon freshly killed material. When badly damaged larvae were placed in cages with sarcophid flies, the flies oviposited on them. These experiments demonstrate that the Sarcophagidae used for these experiments are not parasites but scavengers.

MISCELLANEOUS INSTINCTS

Migrations. M. D. Hill (28) describes a case of dragon-flies migrating in swarms.

A moth (*Tortrix fumiferana* Clemens) in July, 1911, entered Philadelphia in such swarms that traffic was interfered with and shop keepers were obliged to close their doors (2).

Hibernation. In the South, according to Glen Herrick (27), the cabbage-aphis (*Aphis brassicae*) hibernates in the agamic form.

According to Burgess (15), *Calosoma sycophanta* hibernates at from two to twenty inches below the surface of the ground. Males and females emerge from the ground at the same time. This statement is based on a study of 734 cases.

Locomotion. According to the Severins (53) *Belostoma* swims rapidly and *Nepa* slowly. In swimming both use only the middle and hind pairs of legs and with these they make alternate movements. In walking on land all of the legs are used by both genera.

In testing how far scale insects can walk without feeding, Quayle (48) traced the paths of specimens which were allowed to walk across large sheets of paper. He studied the black scale (*Saissetia oleae* Bern), the red or orange scale (*Chrysomphalus aurantii* Mask.) and the purple scale (*Lepidosaphes beckii* Newm.). The rate of locomotion varied with the tem-

perature. The maximum distance traveled by the black scale was four feet.

DIVISION OF LABOR

E. A. Andrews (9) asserts that each caste of the termites has its special work to do. "The workers do all of the mechanical work; bite off and transport the wood; feed the soldiers and males and females; clean the males, females and soldiers; remove the eggs from the orifice on the end of the female and clean and transport them; do all the work of arcade and nest building and all the biting in defense of the community. The soldiers do no mechanical work, except to move themselves; they appear first when the nest or arcade is disturbed, they explore what is novel, lead the advance of processions, stand placed like guards along the side of processions. They respond to anything unusual rather by exploratory advances than by retreat, being the quicker moving and more responsive members of the community. They form the "investigator rather than the soldier caste. Yet they fight, in a refined way, by ejection of a secretion that binds the enemy fast." There is no overlapping of the functions of one caste by the functions of another such as Miss Buckingham* found to be true among ants.

HOMING

Hardy (26) noticed a *Diamma bicolor* dragging a cricket to her burrow. The wasp was moving backwards. Often she stopped to reconnoiter; but always continued in the same general direction. When the cricket was removed by Hardy from the place where it had been deposited and placed six inches to one side, the wasp became very much agitated and made a random search, going over the same ground several times. At one time the cricket partly revived, and became somewhat active. The wasp stopped her tugging and stung it again.

Andrews (9) found that a small object placed across the trail of termites would cause both the outgoing and the incoming individuals to halt when they arrived at it. Finally they would construct a spur around the obstacle to the trail beyond. This caused Andrews to conclude that the termites are guided by a sense akin to smell. He thinks they are also partly guided

* Buckingham, E. N. Division of Labor Among Ants. *Proc. Amer. Acad. of Arts and Sciences*, 1911, 16, 425-507.

by a sense of direction; but can hardly be said to have established this last point experimentally.

SOUND-PRODUCING ACTIVITIES.

During the year, Allard (3-7) has produced several papers on the stridulations of the Orthoptera. In one (4) he gives a general discussion of the subject and describes methods of studying this form of behavior; in the other papers (3, 5, 6, 7) he discusses in detail the sounds produced by a large number of species. The statements in the remainder of this paragraph are condensed from the paper (4) containing the general discussion. Stridulating powers are highly developed in the Acridiidae, Locustidae and Gryllidae; the last mentioned being the most musical and the first the least. Strident sounds of insects are always of an instrumental and never of a vocal sort. Usually musical sounds are entirely absent; when present they are usually of a continuous monotonous tone. Except some Acridiidae, which stridulate by movements of the hind legs against the tegmina, the stridulations of the Orthoptera are produced by definitely controlled movements of the tegmina, which have been modified for that purpose. Among the Acridiidae that stridulate during flight the inner wings are brought against the tegmina at will. Among the more highly specialized Locustidae a portion of the base of the tegmina has been modified for sound production. The wings of the Gryllidae show the most complete modification. Entomologists have neglected to study the musical habits of the Orthoptera, hence the stridulations of only the common forms are known. Attempts to reduce the sounds to music have not been wholly successful, because the sounds are usually unmusical. All of the Gryllidae, however, have true musical tones. Slight changes in the light, temperature, and moisture have peculiar, but specific, influences upon the character of the stridulation. Forms that in summer stridulate only during the night, in the cool fall often stridulate only during the day. In the summer time, the atmospheric condition preceding a thunder storm at night causes many Orthoptera to be musical until the storm has passed. Marked differences in stridulation may characterize certain species in different parts of their range; this is especially true of *Gryllus pennsylvanicus*.

C. Pemberton (44) has described the stridulation of the shield-backed grasshoppers *Neduba* and *Aglaothorax*. In these genera the elytra of the males are highly specialized for sound production.

G. T. Lyle (34) records the stridulation of the pupa of an ichneumonid.

Two beliefs are extant as to how sounds are produced by the Diptera and by the Hymenoptera. Landois, who has been regarded an authority, held that, in addition to a sound made by the wings, flies, gnats, bees and wasps produced a finer sound, by means of an apparatus connected with the spiracles and tracheae. Pemberton (45) has conducted a series of experiments to test the validity of this view. In those experiments he used the bumble-bee, the honey-bee, the house-fly and several species of Syrphidae. When a fly was held by the legs in such a manner as to permit free movements of the wings, two sounds were heard; one of low pitch, caused by the vibration of the wings, and one of high pitch, caused by the bases of the wings striking against the body. When a fly, the wings of which are reduced to stumps, is held by the legs, a single sound of high pitch is heard. If the stumps of the wings be touched or if they be glued to the body, no sound is produced. If the thoracic spiracle be completely destroyed by means of a needle, and the abdomen cut off, if the wings are left free, a high pitched buzz of short duration is produced. When the wings are pulled from the fly in such a manner as to leave no stubs, no sound is produced. These experiments caused Pemberton to assert that there is no spiracular voice in either the Diptera or the Hymenoptera.

RELATION BETWEEN GAME AND THE TSETSE FLY

Throughout South Africa, according to Hamilton (25), there is a widespread belief that the "big game" mammals are responsible for the spread of the tsetse fly. Many have advocated the destruction of all big game in order to destroy this fly. The relation of the tsetse flies to sleeping sickness and to cattle and horses has aroused great interest in its habits. As a result last year saw the appearance of several articles (20, 24, 25, 38, 50, 55) treating of the habits and the habitats of the tsetses. To those interested in the economy of the species, all of these articles will be of value. Two of them (25, 50) produce conclu-

sive evidence that the presence of "big game" is not essential for the existence of these flies, and that the destruction of the large mammals does not necessarily destroy the tsetse fly. The deduction is based on the following evidence. According to Sharpe (55), when the rinderpest destroyed much of the game in Nyassaland, there was no diminution of the number of tsetses. J. S. Hamilton (25) asserts that in certain regions hunters have almost destroyed the large game without causing any perceptible diminution in the number of tsetses. Both of these men assert that the fly often exists in great numbers in regions where there is no large game and is sometimes absent from regions where there is an abundance of game.

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LITERATURE FOR 1911 ON THE BEHAVIOR OF ANTS AND MYRMECOPHILES

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Bouvier (1) observed the moving habits of the harvesting ant, *Messor barbarus*, at Royon. This ant nests in very large colonies in subterranean nests, of which one colony may have more than a single one. When conditions in one nest are unfavorable, the ants move into another taking with them their young and the stores of grain. During the process of moving a preliminary body of ants go out. These travel in two columns from one nest entrance to the other. The transportation of the larvae, pupae and the food supply is carried by a double column also. The small crustacean, *Platyarthrus hoffmanseggi*, which lives in great numbers in the nest entrances of *barbarus*, follows the ants from one nest to another, probably finding the new abode of the ants by the scent trail which these have left.

Buckingham (2) made very extensive experiments on the division of labor among ants as correlated with size and structural differences. The ants used were two species of *Camponotus* (*C. americanus* and *C. herculeanus pictus*) and three of *Pheidole* (*Ph. pilifera*, *Ph. vinelandica* and *Ph. dentata*). *Camponotus* was chosen because of the presence of large and small workers connected by intermediate forms, and *Pheidole* because it has small workers and large soldiers, without intermediate forms.

A tabular arrangement of measurements of *Camponotus* shows that there is a perfect gradation between the largest and the smallest workers, both in size and in structure. Structurally the queen is most closely related to the major worker. In *Pheidole*, no such intermediate forms exist, and the queen similarly is more like the soldier, though resembling the worker in certain characteristics.

In working with ants in artificial nests it was found that the ants were stimulated by a rise of temperature rather than by light, remaining quiet at 22° in a good light, but moving about

when the temperature was raised from 19° to 20° and 21° C. The stimulus was assumed to be not simply heat, but a rise in temperature.

Experiments were made with ants in Fielde, aluminum and Barth nests, and observations were made on outdoor nests. With the latter field notes were used, and ants engaged in various activities were collected and the data recorded. The activities tested were 1, foraging; 2, partaking of different foods; 3, feeding themselves; 4, regurgitating to others and receiving regurgitated food; 5, licking each other, likewise being licked; 6, tending the young; 7, building; 8, carrying other ants, likewise being carried; 9, surrounding the queen; 10, fighting; 11, responding to disturbances of the nest; 12, guarding; 13, scavenging.

An elaborate series of experiments was made, not only on the relation of the size to the labor, but also in regard to age. Callows, or recently hatched ants, acted chiefly as nurses, taking no part in the defence of the colony or in building. The size of the various workers was shown to be well correlated with the activities, most of the work in the nest and the foraging being done by the more active, smaller forms. The majors, both in *Camponotus* and *Pheidole*, were ordinarily sluggish, but easily stimulated by the nest's being disturbed, when they became more active than the minors in defending the nest. This is a valuable adaptation, keeping the majors in readiness and reserve for fighting. Buckingham shows that workers and even queens of various sizes participate to some extent in the activities of the colony, but a preponderant number of those working (with the exception of defending the nest, comparatively few of the ants in a colony are working at any one time) showed distinctly that the functions of the ants of different size are correlated with their structural differences.

Champlain (3) records the capture of *Xenodusa cava* in numbers in Connecticut, on tree tanglefoot which is used to trap the fall cankerworm. Ants also had fallen victims.

Cornetz (5, 6, 7, 8) and *Cornetz* and *Bohn* (11) in Algeria studied the homing of several hundreds of individual ants. Seven species were observed. An ant on going away from the nest strikes out in a definite direction, which it maintains in a general way throughout the out-going trip. From time to time

in searching for food it deviates but always resumes the original direction. To an ant (Messor) at several meters distant from the nest, Cornetz gave a seed. It took this in its mandibles, turned about and returned directly to the nest. This experiment was repeated a great many times, always with the same result. The line of return was more direct than the outgoing line, which was rather sinuous, with frequent deviations. The axes of these curves were followed in returning, and these led, with slight inaccuracies, toward the nest. In the immediate vicinity of the nest the ant stopped and searched for the entrance, showing here a realization of having gone a certain distance. This sense is quite variable. Sometimes the ant stops altogether too soon. When the ant first experimented upon was away from the nest Cornetz changed the aspect of the returning line by sweeping, digging ditches and bringing piles of earth or rubbish. The ant returned without hesitation, along a nearly direct line toward the nest. This experiment, which was repeated many times, shows conclusively that sight, smell, touch, chemotropism or topochemism play absolutely no rôle in the return of the foraging ant to the nest, except in the immediate vicinity of the entrance, when these senses may be brought into play. As far as these experiments went they seemed to show the existence of some mysterious "homing" sense, but further experiments were made that utterly disproved any such supposition.

On a plantain leaf, left in the vicinity of a nest until the ants had become accustomed to its presence, Cornetz placed a number of seeds. An ant (a large Messor) climbed upon this and seized one of the seeds. Cornetz carried the leaf several meters away and placed it again on the ground. The ant was then absolutely incapable of returning directly to the nest, but began to wander about, increasing the extent of its searching, but not further on one side of the point than on the other, until it approached the immediate vicinity of the nest. This experiment, repeated 150 times, always gave the same result. When carried to a distance of two or three meters from the nest, it took from a half to three-quarters of an hour before the ant could find the nest entrance, which, had the ant walked such a distance from the nest, would have taken only a minute or two. From this it is evident that the ant possesses no sense

of direction. The return after going out from the nest is explained by assuming that the sensorium of the ant receives a sensation of direction on the outward trip. This sensation is received at the beginning of the trip and maintained throughout its course, for no matter how many times the ant deviates from the general direction it returns each time. This phenomenon Cornetz calls "the constant reappearance of the once impressed wandering direction." This direction memory of the trail may be of greater complexity. When ants had become accustomed to a pile of grain at a certain point, the grain was removed some distance. The ants diverged from the old spot, found the grain and returned to the point at which they had left the outgoing trail, and then went directly to the nest. Here a memory of two separate directions is shown. The secondary trails, diverging from the principal outgoing trail, were at right angles to it.

Cornetz concludes from these observations that sight, smell, touch, chemotropism and topochemism play no rôle in the return of a solitary foraging or hunting ant, but that it is guided by an impression received by the sensorium at the beginning of the outward trip. From the fact that the outward trail is sinuous while the homeward is more direct, it is evident that the ant does not possess a kinometric muscular memory. Touch, smell and sight are probably valuable in guiding the ants in the immediate vicinity of the nest, where they lose the earlier impression of direction. But after a heavy rain, that had lasted two days and changed completely the general surroundings of the nest, the ants went out and returned as readily as before, when they had been familiar with the immediate vicinity of the opening.

Cornetz (9) reviews *Santschi's* paper "Observations et Remarques Critiques sur le Mécanisme de l'Orientation chez les Fourmis," in which the effect of the sun's rays was said to be an important factor in orientation. This phenomenon Cornetz calls the "solar tropism of *Santschi*." He considers that it helps greatly in explaining the constancy of orientation, but doubts its application to ants moving about in the deep woods, or in the shade in general, unless we assume that certain as yet unknown rays of the sun penetrate through walls, trees, etc., not being absorbed by these bodies. When the sun was

very high, Santschi's experiment was not successful, and Cornetz points out that beneath the equator, with the sun more or less perpendicular to the line of march, the ants are able to maintain their direction.

Cornetz notes a case of a memory of direction in *Myrmecocystus bicolor*, which had moved from one nest to another, and for a long time traveled between the old and new nests.

Davis (12) records the occurrence near Clayton, Georgia, of a mixed colony of *Formica exsectoides* and *Formica subsericea*, representing one of the stages in the colony formation of the former species, which is a temporary social parasite.

Donisthorpe (13) placed the larvae of a Chrysomelid beetle (*Cryptocephalus fulvus* Greg.) in a plaster nest with a few of its host ant, *Lasius fuliginosus*. The larva acted like that of the related genus *Clythra*, crawling about and feeding on the refuse of the nest, and enlarging its case as it grew. When the adult beetle emerged it was torn to pieces, either by the ants or by other myrmecophiles (*Myrmedoniae*) which were present. In nature the mature beetle would escape from the nest.

Donisthorpe (17) placed workers, eggs and larvae of *Formica exsecta* Nyl. into a small nest of this species which the year before had been taken near the same spot. The workers intermingled freely and behaved in a friendly manner towards one another. He records *Lasius umbratus* as collecting small empty land shells, and sitting on them. No explanation is offered of this curious behavior.

Two colonies of *Leptothorax acervorum* were placed together, and apparently affiliated to form one colony. Donisthorpe has never reared a female from eggs laid in captivity, and suggests that the juices obtained from aphids may be necessary to the development of the female larva.

The myrmecophilous beetle *Atemeles emarginatus* Pk. was taken from a nest of its winter host *Myrmica scabrinodis*, and placed in a nest of *Formica fusca*. The beetles remained away from the ants for twenty-four hours, when, joining the ants, they were readily received. This is regarded as additional evidence that these beetles go into quarantine when leaving the nest of one species of ant before entering that of another.

A spider, *Asagena phalerata*, was observed catching ants (*Myrmica laevinodis*). It kept at some distance from the ant

and "threw the threads" of web at it. Four or five ants were entangled together and carried off. The mite *Laelaps cuneifer* Mich. was observed to follow the "tracks" of the host ant when it went from one nest compartment to another.

Donisthorpe (15) records observations on the behavior of certain ants that are temporary social parasites. Experiments were made with *Formica sanguinea* Latr., the only English slave-making ant, and its host, *Formica fusca*. Workers and pupae were placed in one compartment of a "Crawley" nest, and two females of *sanguinea* in another. As soon as the latter became aware of the presence of the *fusca* cocoons, "they hurried in, attacked and killed the *fusca* workers and carried the cocoons to their own compartment." The adults from *fusca* cocoons which were placed in the nest, were assisted in emerging by the *sanguinea* queen.

To prove that *sanguinea* females are unable to found colonies by themselves, Donisthorpe placed several in bowls. They hid beneath pieces of sponges, but made no attempt to dig cells. A few eggs were laid, but neglected, and therefore did not hatch, thus corroborating other experiments and seeming to indicate positively that *sanguinea* depends absolutely upon a temporary host to found a colony.

Emerton (18) states that the spider *Phrurolithus formica* Banks is found only in the nests of *Cremastogaster lineolata*. In the spring, when the ants are gathered under stones over their burrows, the spiders are found among them. If not frightened, they move about slowly, like the ants, but when frightened are much more active, and run either into the ant burrows or into the grass about the nest.

Emery (20, 21) studied the mating and colony-founding habits of *Polyergus*. There is no doubt that marriage-flights occur frequently with *Polyergus*, but copulation may also take place in the nest. Queens, both dealated and winged, have been frequently observed in company with raiding-columns. In one colony observed by Emery for two years, the marriage-flights occurred the second year, but not during the first. The first year, queens were found with raiding-armies. Of these Emery sent one dealated specimen to Silvestri, who found the *receptaculum seminis* full of sperm. A winged female taken at the same time was not fertilized. No queens were found in the

columns of workers outside the nest during the second year, and Emery considers it possible that marriage-flights may depend on the number of sexual forms, especially of males. Where there are only a few of these copulation takes place in the nest.

In founding a colony, one or more *Polyergus* queens enter the nest of *Formica fusca* or some variety of that species. When not prevented by the workers the parasitic queen goes directly to the *fusca* queen and kills it by piercing its brain with the sharp mandibles. The demoralized *fusca* workers then readily adopt the alien queen. Some of the *Polyergus* were killed by *fusca* workers before reaching the queen. This was in a Janet nest, which is particularly favorable to the *Polyergus* queen. In nature the killing of parasitic queens probably occurs more often.

It is important to *Polyergus* that the host colony be populous. This Emery believes to be true of all parasitic ants. If the colony selected by the queen is small, the primitive stage of the *Polyergus* colony may last two years. During the first year no eggs are deposited. The second year eggs are laid and workers develop, but no raids are started until late in the summer, sometimes not until the third year, when the colony is fully developed.

Emery (19) studied the relations of fecundated females of *Pheidole pallidula* toward each other. They oviposit a few days after fertilization, and when placed together in an artificial nest fight and tear the antennae and legs of one another. The individuals without antennae become indifferent to the eggs, so that their care falls to the lot of the female that has preserved her appendages. Eggs laid early in July gave rise to workers August 15th. After three separated females had been permitted to bring up their broods, Emery made openings between their cells. The workers at first tried to obstruct the openings. The workers of two of the colonies fought with one another. When the queen of one of these was killed her brood was appropriated by the other. Later the two remaining colonies behaved in the same manner till only one female remained and the broods of all three colonies were united. When several females were permitted to found their colonies in close proximity to one another, similar results were obtained. Emery concludes that recently fecundated queens of *Ph. pallidula* live together amic-

ably till they have oviposited, but that discord supervenes with maternity and the attraction of the ova.

Experiments with dealated queens of *Tetramorium* yielded somewhat similar results, but out of fifteen queens that reared their broods together, three survived. In other species of ants the queens are even more tolerant of one another, e.g., *Plagiolepis pygmaea* and *Leptothorax unifasciatus*. In this connection Emery calls attention to the Argentine ant (*Iridomyrmex humilis*), the colonies of which, according to Newell, may unite in great numbers in the fall, producing enormous hibernating colonies, each containing hundreds of queens.

Emery (22) shows that larvae which are insufficiently nourished produce weak and undersized workers. These inferior workers are found in the first brood of a queen and in colonies where the worker force is small numerically. As the success of a colony of robber-ants depends on the presence of large, strong workers for fighting, Emery considers that a populous host colony is necessary. Social parasitism having arisen, in the opinion of Emery, from nest-robbing habits, this necessity for a large force of workers to attend the young has been an important factor in its origin.

There is no transition in habit from the forms of *fusca*, through to the typical social parasites, *rufa*, *truncicola*, etc., so Emery considers that the social-parasitic habit originated from a mutation rather than by a gradual development. In *sanguinea* the mandibles of the male are toothed, while in *fusca* they are smooth, which shows that the latter species is even more specialized than the former.

Enslin (23) observed *Formica cinerea* attending the small European Membracid, *Gargara genistae*, which he found in numbers on *Sarothamnus scoparius*. The plant was frequented by ants which were foraging and also attending a few aphids in the ordinary manner. When one of the ants finds a *Gargara* nymph it strokes the abdomen with its antennae. The tree-hopper elevates the abdomen and from the anus exserts a rod-like structure on the end of which is a drop of light-colored liquid which the ant imbibes. Then the ant either tries again on the same individual or hunts for another. If the head or thorax instead of the abdomen of the bug is stroked the result is the same. Adults of *Gargara* are also attended, but not so

frequently as the immature stages, possibly because the drop is harder to get at on account of the wings. One adult was stroked for some time by an ant and failed to respond, but a half minute later when the ant had gone it spontaneously ejected a large drop, which was found and lapped up by another ant.

Enslin placed specimens of both the immature and mature phases of the tree-hopper in the immediate vicinity of a *cinerea* nest. Sometimes an ant received a drop of secretion from the Homopteron and went on its way. Others took the insect in their mandibles and attempted to take it into the nest, sometimes successfully. At other times the insect struggled too much. The fate of those taken into the nest was not observed. Without access to its food plant the insect could not secrete the liquid for which the ants attend them; besides, those which Enslin kept without food died within two days. It may be that those adults brought in after copulation deposit eggs in the nest, but nothing definite regarding this is known. In fact, only scant observations on the relations between any Membracids and ants have been recorded.

Escherich (24) in Ceylon studied the "myrmecophilous" plant *Humboldtia*, the stems of which have hollow internodes, each with an opening at the upper end. The leaves are provided with nectaries that afford a food supply to ants, several species of which nest in the hollows, and Schimper had considered the plant typically myrmecophilous. Escherich found that only a small percentage of the internodes were used as nesting sites by ants, and that these were species which nest in various other places also. Unless the twigs were violently shaken the ants made no attempt to defend the plant. Many of the occupied stems showed scars made by woodpeckers attracted to the ants, so Escherich concludes that the relationship between plant and ant is in no wise symbiotic, but rather parasitic, as the latter derives its shelter and food from the former, giving no service in return, and even being directly harmful through attracting enemies. Escherich believes that records of symbiosis based on the study of the plant structure only, without observations on actual relationships, are not worthy of consideration.

In Abyssinia Escherich observed the foraging habits of a species of *Messor*. During the day the ants remained in the nest. At nightfall they emerged, leaving the nest by a distinct trail

which was followed 30 or 40 meters. Then they spread out, some climbing weeds in search of seeds. When food was found the ants returned by the same trail, which was then being traversed by two files of ants moving in opposite directions. The seeds gathered were of numerous varieties. Some of the foragers returned carrying lumps of earth, small stones or other worthless objects, a fact tending to show variability in the grain-collecting instinct. At the nest entrance several large workers acted as guards and examined with their antennae the returning workers before allowing them to enter the nest. The husks from seeds were brought out of the nest very quickly and taken to some distance.

Among the foods collected by the ants were many tubers from the root stalks of *Cyperus bulbosus*, which are eaten also by the Abyssinians. Their carrying these about may possibly be of importance in the dissemination of the plant species.

Goeldi (25), in an account of the structure and character of the ant nest, introduces the term Gonepitropy for the assumption of the reproductive functions by the queen. The workers have taken over the functions of food-gathering and nursing for the entire colony, and this Goeldi calls Ergepitropy. The workers Goeldi does not consider to be degenerate females, but rather a distinct caste, fitted for the work that is done by them.

Krausse (26) records a few observations made on *Aphaenogaster sardoa*, a characteristic Mediterranean ant. The holes in which this ant lives are not dug by it, but have been made previously by other animals or natural means. In the fall the ants cluster into a ball, holding on to each other with mandibles and tarsi, with the eggs, larvae and pupae in the center, and remain in a semi-dormant condition. This habit is analogous to the hibernation of northern ants. In summer the clustering habit to some extent persists, but the ants are much more active. Krausse placed a number of workers with pupae in a glass nest and after a half hour found them in a compact cluster, the pupae in the middle. When dispersed, they again built a cluster. No myrmecophiles were found with *sardoa*, and Krausse considers their absence related to the non-harvesting and non-cell-building habits of the ant. The larva-robbing *Dermapteron*, *Euborellia moesta*, which steals from the nests of other ants in the same vicinity, was not found with *Aphaenogaster*,

probably because of the larvae being in the center of the ant cluster where they can be taken only by a direct attack, a method to which few inquiline thieves resort.

Krausse lists a number of ants which are known to possess stridulating apparatus. In some of the species the sound produced is loud enough to be heard by the human ear.

Krausse (27) in Sardinia found carton nests built beneath stones by *Cremastogaster scutellaris*. Besides, *C. scutellaris*, *Lasius fuliginosus* and *Liometopum microcephalum* are European ants which make carton nests.

With *C. scutellaris* myrmecophilous insects were rare. One specimen of the robber earwig, *Euborellia moesta*, was found in the nest of this ant.

Krausse (29) observed two ant trails which crossed each other. The trails were made by different species of Messors, and led from nests which were very close together. Ants in the files going and coming showed sometimes a little excitement at the point of crossing, but no actual fighting took place. They would lunge at each other without taking hold.

Krausse (28) records an earwig, *Euborellia moesta* as occurring commonly in the nests of several ant species in Sardinia. Its relation to the ants is that of a robber, and it destroys large numbers of the larvae. *Forficula auricularia* was also observed to enter ant-nests and feed on the immature stages.

Leonard (30) records observations made on "honey" ants, *Myrmecocystus mexicanus mojave*, *M. mexicanus* and *M. melliger lomaensis*, all found on the grounds of the Raja Yoga School at Point Loma, Cal. *M. mojave* prefers a moist soil in which to nest. Leonard believes that the large entrances to the nests are required for the removal of iron nodules encountered in digging, and not for purposes of ventilation as suggested by Wheeler. This new view presupposes large quantities of iron nodules in all regions inhabited by *mojave*, for the habit of making large entrances is characteristic of the insect throughout its geographical range.

Individuality in character was shown by a minor worker. When one of the ants had fallen into a moat two workers discovered and inspected it without offering aid. Then the minor approached and "showed the liveliest concern. For many

minutes she vigorously kneaded the patient's gaster, and worked the stiff legs until at last the half-drowned ant revived." The ants gather honey from blossoms of a pepper tree (*Schinus molle*) and from *Euphorbia setiloba*, *Echinus simplex*, *Ceanothus cuneatus*, and from aphids.

Callows, after emerging, were carried out of the nest by older workers "as a hint that they might now undertake the regular work of the nest."

Myrmecocystus mexicanus was observed to lap the honey contents of dead repletes, contrary to the recorded observations of McCook on the var. *horti-deorum*. *Myrmecocystus lomaënsis*, a diurnal species, became violently excited when it was offered bee's honey.

Miehe (32) studied the plant *Myrmecodia* in Java in relation to ants. *Myrmecodia tuberosa* possesses a swelling in the stem, originating from the hypocotyl. This swelling is perforated by a complicated system of cavities. One or more large openings connect these with the surface, and smaller openings are also present. In the inner spaces of the cavities numerous species of ants take up their abode. These sally out when the host plant is struck, but are not particularly aggressive.

Forbes and Treub found that these cavities were developed without the presence of the ant, in contradiction to earlier opinions. Treub considers that they are useful to the plant in transpiration. Kaesten regarded the swelling as an organ for the economy of water, the wart-like objects (*lenticels*) which line the cavities being absorbent organs, and Miehe also considers them to have the same function. They are also supposed to excrete water.

One part of the cavity walls is light in color, smooth and without tubercles, the other is tuberculate and dark in color. On the latter surface flourishes a fungus, which in the opinion of Miehe grows on the excrement of the ants. The ants have their larvae and pupae always on the smooth surface, and deposit their excrement on the rough part, a habit similar to that recorded by Von Ihering for the Azteca queens of the South American *Cecropias*. According to Miehe the food products in the ant excrement must be important to the epiphyte.

The fact that the ants drop their excreta on the exact place where the absorbing organs are situated, and that this is of

importance to the plant, is taken as evidence of myrmecophily, but whether the dung is actually necessary to the growth of the plant is not known. The plant has few natural enemies, so its defense by the ant is not to be considered. *Iridomyrmex myrmecodiae* lives in other places as well as in the hollows of *Myrmecodia*, so that the plant is certainly not necessary to the ant. *Hydnophytum montanum* is recorded as having similar relations to the ants.

Nickels (33) experimented as to the possibility of exterminating the Argentine ant (*Iridomyrmex humilis*) with entirely satisfactory results. Sponges, moistened with sugar syrup, containing one-fourth to one-eighth per cent. sodium arsenate, were placed in the neighborhood of the nests. This was eaten by the ants, and fed to the queen and brood, slowly poisoning them and shutting off the increase of the colony.

Polimanti (34) in Naples observed large numbers of the winged forms of *Lasius niger* attracted to large arc-lights, while comparatively few came to incandescent and other less bright lights. He attributes this to simple phototropism.

Poulton (35) published some notes made by Lamborn, who had noticed that the larvae of Lycaenidae in the Lagos district were often attended by ants. Examination of the ant-nests in the hollowed head of a plant (*Castus afer*) showed that each contained several caterpillars and pupae. These were attended and licked by the ants, but the adult butterfly was killed and eaten. Lamborn observed the ant *Oecophylla smaragdina* attacking the larva of a Lycaenid. This ant has been observed frequently to tend the caterpillars. The larva of a Pyralid moth also lives in the nest.

Reichensperger (36) confirms the observations of Wasmann that in nests of *Formica sanguinea* infected with the beetle *Lomechusa*, normal queens and pseudogynes are not developed at the same time. The pseudogynes which he found were intermediate between those forms which Wasmann calls Mikro- and Mesopseudogynes. The percentage of these abortive females in the brood gradually increased, the slave-making raids were not continued, and those pupae already taken were not cared for, the result being the weakening and the final disintegration of the ant colony, as a result of the presence of *Lomechusa*.

Reichensperger observed for the first time the first stage in the temporary social parasitism of *Formica pratensis* in the nest of *Formica rufibarbis* var. *fuscoringularis*. The alien queen was very readily adopted, "treated as though she were the only one," one beginning to lay eggs after one week. *Pratensis* queens are not always so successful, as was shown by the finding of dead and dismembered individuals in other nests of *rufibarbis*.

Reichensperger records the discovery of a microgyne of *Plagiolepis pygmaea*. One of these small queens in an artificial nest laid eggs from which normal workers were reared. The microgynes were similar to the queen in structure, but in size about as large as the workers, from which they differed in color as well as structure.

In a postscript Reichensperger states that he may not have been correct in his specific determination. The microgyne may have been a guest species, or an incipient new species derived from *P. pygmaea*.

Sadownickowa (37) made a series of 42 stereoscopic photographs of various activities of European ants. Among the lot are pictures of the nests of several species, life histories, foraging individuals, parasitic colonies, fighting, and mixed colonies. Photographs No. 40 and 41 show ants of different species, from which the antennae have been removed, living peaceably together. In the lot are workers of *Camponotus ligniperdus*, *Formica sanguinea*, *Formica rufa*, *Formica fusca*, *Messor barbarus*, a female of *Formica sanguinea* and a male of *Lasius niger*, all feeding on honey water. The antennae of the male have not been removed, but it is apparently unable to distinguish between friend and foe.

Santschi (38) studied the behavior of several species of North African ants in regard to orientation. Certain of these (*Acantholepis frauenfeldi* and *Tapinoma nigerrimum*) made a scent trail by touching the tip of the abdomen to the ground. *Myrmecocystus bicolor*, with the antennae removed, found the nest, at first wavering somewhat but more directly as it neared the nest, evidently familiar with the immediate approach. Here sight seems to be an important factor. *Messor barbarus* proceeded in the general direction of its nest, though the ground over which it had come had been swept and otherwise disturbed,

so as to leave no possibility of guidance by scent or the sight of immediate objects. The sight of this ant is poor so that objects at a considerable distance from the ant could have had no effect, so the experiments agree with those of Cornetz and other workers in showing the constancy of conservation of orientation. Santschi explains this by assuming that on the outward-going trail certain rays of light (probably ultra-violet) make an impression on the pigment of the ant's eye. Owing to the structure of this organ these impressions are unequal in various parts and are retained, making a sort of compass to orient the ant on its return. By means of a mirror, Santschi changed the direction of the light rays on homeward bound ants. Under this influence the ant changed its course, but orientated itself toward the nest when the mirror was taken away. Santschi considers the "homing" sense a very complicated phenomenon, involving many factors; but above all, the perception of these physical rays, visible or not to us, is valuable as a basis for orientation.

Tanquary (39), in order to determine whether they would be adopted, placed queens of *Aphaenogaster tennesseensis* with colonies of *A. fulva*, *A. fulva aquia*, *A. fulva aquia* var. *picea*. In all cases the queen was eventually killed by the workers of the other species, but a tendency toward adoption was shown by the fact that the queen was often licked by the workers. A queen of *A. tennesseensis* was placed with pupae of *A. aquia*. She paid no attention to these. Some hatched, and at first the queen remained by herself, but afterwards stayed with them, and was readily adopted, as in the cases recorded by Miss Fielde (Artificial Mixed Nests of Ants).

Queens of *Formica rufa* subsp. *obscuriventris* were placed with colonies of *Formica fusca subsericea*. Where the colony was large, the queen was killed; when small, after being attacked for a time, she was finally adopted. The queens showed decidedly inquiline habits, and this, with the fact of their being adopted by small colonies, with the previous finding of a mixed colony in nature, shows that *F. obscuriventris* is, at least occasionally, a temporary social parasite in the nests of *F. subsericea*.

Experiments were made with 79 queens of *Lasius (Acanthomyops) latipes*, introducing them into different colonies of other

species of *Lasius*. Of all these, only two queens were completely adopted. This low percentage can be partially explained by the difficulty of keeping queens of *L. latipes* alive in confinement. It is doubtful if in nature even this small proportion of the queens succeed in forming colonies, for colonies of the species are not very abundant, in spite of the fact that a great number of queens are produced in each colony.

Queens of this species and of *Lasius americanus* were placed together. Neither species showed hostility toward the other, though their temperaments were decidedly different, *latipes* being very restless, and running constantly about. The fact that both species of queens lived amicably together might be taken to indicate that mixed colonies may be founded in common by two queens of different species, but the nervous behavior of *latipes* and its attraction to any brood, with which it settles contentedly, is taken by Tanquary to show that it is more plausible to believe that this species is a temporary parasite.

Experiments were made with 88 queens of *Lasius umbratus* var. *minutus* and workers of several other *Lasius* species. Of this lot only one queen was adopted by *L. americanus*. But this one case indicates that *minutus* is parasitic on *americanus*. The *minutus* queens are feeble, and easily killed, succumbing to treatment that would not be fatal to ordinary species. The sporadic occurrence of the species, with the large number of queens produced (a quart of earth from the one nest was found to contain about 150), is taken as justification of this conclusion.

Queens of *Polyergus lucidus* were placed with colonies of *Formica incerta* and *F. schaufussi*. The queens were attacked by the workers, but defended themselves with vigor, one of them killing all of the fifteen workers with which she was confined. In two experiments the queen was adopted by *incerta* after being at first attacked. An *incerta* queen in one of the nests was killed by *Polyergus*, after which the workers adopted the alien queen. In no case did any of the *Polyergus* queens pay any attention to the young.

Queens of *F. nepticula* were tried with colonies of *F. incerta*, *F. fusca* var. *subaenescens* and *F. neogagates*. With the first two the results were negative, the queen being killed very soon,

but with *neogagates* the attacks were not so fierce. Several times workers were observed licking her, and she was twice observed feeding a worker. She was finally killed.

Viehmeyer (40) studied the mating flights in several species of ants. These flights have a double purpose, to distribute the species and to prevent close inbreeding. The flights of the same species occur at approximately the same time, and at these times sexual forms from many nests mingle together in an enormous swarm, so that the individuals from one nest copulate with those from another. The wings of queen ants are very brittle and weak, and the presence of a strong wind blows the ants about, scattering the species to long distances.

Often many species of ants have their mating flight at the same time, and join in one common swarm. One of these swarms was observed by Viehmeyer. It consisted of two species, *Myrmica scabrinodis* and *M. ruginodis*, with the latter greatly predominating in numbers. When numbers of pairs had fallen to the ground they were collected. Of the lot, only about one-sixth were of the same species, and in every case these were *ruginodis*. Most of the couples consisted of a *scabrinodis* queen and a *ruginodis* male. The males of both species predominated in numbers over the females. Hybrids between ants are sterile, and Viehmeyer does not consider that hybridization has any importance in the phylogenetic history of the species.

Wasmann (42) treats, in a very general way, ants and their guests, dealing especially with social parasitism of the former, and the relations of the latter to their hosts. Some two thousand species of Myrmecophiles have been recorded. These Wasmann has separated, according to their relations to the host, into five classes, (1) Symphiles, or true guests; (2) Synoeketes, or indifferently tolerated guests; (3) Synechthrans, or persecuted guests; (4) Ecto- and endoparasites, and (5) Trophobiotic symphiles. A short account of the Symphiles is given. With the legionary, or driver ants are three types of guests, called by Wasmann symphilic, mimetic and protected ("Trutz") types. The latter are tolerated by the ants because they are unable to destroy them. This paper is a very excellent general account of the subject, and is illustrated with several photographic plates.

Wasmann (44) shows that in species of *Atemeles* living with different hosts, varieties have originated which have characters correlated with certain characters of the host. These are differences in size, color, sculpture and especially in abundance of hairs. Such forms, he believes, should be considered as varieties or subspecies and not as aberrations, as has been suggested by other writers. These variations adapt the beetle only to its summer host (*Formica*), each species of which has its particular form of guest, while with *Myrmica*, the winter host, several varieties of *Atemeles* may live.

Wasmann (46) describes a new *Paussus* from Ceylon, and gives a list of the host ants of the family Paussidae, so far as these are known. The hosts of only a small number (about one-sixth) have been recorded. The Myrmecine ants, especially of the genus *Pheidole*, most commonly harbor the beetles, but several live with Camponotinae, and one species, *Arthropterus brevis* West., lives with *Ectatomma metallicum*, an Australian Ponerine ant. None have been taken in nests of the Dolichoderinae or with the Dorylinae. The Paussidae are the oldest known ant guests, occurring in the Baltic amber. These amber-imbedded forms are similar to living species, and the branching of this family from the Carabidae must have taken place at a very early date. Wasmann doubts whether the structure of the beetles is the result of symphilic life, and points out the fact that *Pheidologeton* is known from the upper Oligocene, while the characteristic host genus, *Pheidole*, occurs first in the lower Miocene.

Wheeler (47) compares the ant colony to an organism, its behavior and structure with a gigantic foraminiferous Rhizopod. The nest, queen, mass of workers and files of foragers represent respectively the shell, nucleus, plasmodium and pseudopodia. The ontogenetic development of the colony is clearly comparable to that of a complete organism. The fecundated queen represents a mobile, fertilized egg, capable of disseminating the species, and also of selecting the site for the development of the colonial organism. The mass of workers make up the nutritive organ. The first of these are nourished with food derived by metabolism from the fat body of the queen, and from her useless wing muscles. The first young soon

begin to forage, to build the nest and to care for succeeding broods. When sexual forms are developed the organism may be considered to have reached maturity. The phylogenetic history is also similar to that of an organism. A complete gradation exists from the solitary female Hymenopteron, through the small colonies of primitive monomorphic workers closely resembling the female, to the large complex colonies of highly specialized, polymorphic ants, conforming in a most striking manner to the biogenetic law.

The phenomenon of budding is represented in certain ant colonies by the production of numerous queens, some of which, each accompanied by a band of workers, separate from the parent colony and found another. Alecithal eggs are comparable to the diminutive queens of parasitic ants, which, incapable by themselves of founding colonies, enter nests of alien species and use the workers as the nutritive organ, until their own young are developed. These temporary and other forms of social parasites are directly comparable to entoparasitic organisms. Ectoparasitism is represented by compound nests of two or more species which live side by side, sometimes mingling freely, but keeping their broods separate. The restitutional tendency of organisms is found in the replacing of destroyed workers by the rearing of more, and in the development by certain workers of ovaries, when the queen is removed.

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LITERATURE FOR 1911 ON THE BEHAVIOR OF VERTEBRATES

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VISION

Fish. C. Hess (13) offers a new piece of apparatus for the study of adaptation in fish. At one end of a dead black tunnel three metres in length he places a five candle power electric light with frosted bulb. At the opposite end of the tunnel and inclined at an angle of 45 degrees to its axis he places a diffusing surface of ground glass. The light from this surface is reflected out to a dish which contains the fish. Large changes in intensity are made by substituting lamps of higher or lower candle power, while fine gradations are obtained by the use of the rotating sector and by moving the lamp. The animals are light-adapted in the sun and then quickly placed in the experimental tank. The animals respond by swimming towards the side of the tank receiving the rays from the ground glass as soon as the process of adaptation is sufficiently advanced.—For example, the carp exposed to the rays of the sun for one-quarter of an hour, show in the first second of time no tendency to swim towards the light when the 5 c.p. light is 30 cm. from the ground glass. After 20-30 seconds in the dark room, they swim toward the lighted side when the lamp is moved back 1-2 metres. After 10-15 minutes adaptation, they swim towards the light when the lamp is 3 metres distant from the screen and the rotating sector set with a 30 degree opening. He concludes that light sensitivity is increased over a thousand fold after fifteen minutes of adaptation. In some cases even a greater increase in sensitivity is found.

He finds an essential difference between the human and the fish eye. In man the retinal pigment even in long exposure to light does not essentially change its position, while in the case of the fish the pigment upon light exposure wanders soon toward the vitreous humor. This may offer a physical expla-

nation for a small part of the process of adaptation, but Hess maintains that the process as a whole is physiological.

The forward migration of the pigment in light exposure alters the general effect of the light. The advanced pigment absorbs relatively more of the short wave-lengths than of the long. In order to obtain a relation of equality (for the fish) between given red and blue lights one must use a blue 4-8 times as intense for the eye with pigment advanced as that used for the eye with the pigment retracted. The pigment absorbs little of the green rays. This is shown by the fact that the fish which collect in the brightest part of the container seek the yellow-green both when the pigment is in the forward position and in the retracted.

The physiological changes in light (monochromatic) intensity incident upon the migration of the pigment might easily be confused with the Purkinje phenomenon, as was done by Bauer. Hess still emphatically denies that there is any such phenomenon present, and reaffirms his old conclusion that the fish are color blind. It is interesting to note that he everywhere emphasizes the low stimulating value of red.

Bauer (1) in an extended reply to Hess (see this journal, Vol. 1, p. 432, for review of Hess' criticism) reasserts his conclusions that the fish in the light-adapted state are strongly stimulated and even terrified by red (rotscheu) and that they behave as though the Purkinje phenomenon were present. In the last paper just reviewed Hess (p. 419) says that Bauer's results are due to error, and that on repeating the experiments upon *Atherina* he finds that the animals *do not avoid the red either in the light-adapted state nor in the dark-adapted state*. If this is true, and Hess' work is everywhere consistent, the bottom of the quarrel drops out. Bauer's contention that the fish when light-adapted are normal in color vision and when dark-adapted are color-blind is absurd upon its face. His only real support of so strange a position lies in the asserted fact that the light adapted fish are "red-shy"—*i.e.*, that in addition to its brightness value red has a peculiar shock effect. Furthermore, from Hess' work on pigment migration we might very well expect a difference between the light-adapted and the dark-adapted fish in their responses to red and blue-green. This it would seem does away effectually with Bauer's claim for a Purkinje effect. The point is more important than would appear at first sight.

The Purkinje effect is absent in the totally color-blind, and if the fish are totally color-blind as Hess maintains, one could not explain a true Purkinje effect.

Reptiles and Amphibians. Experiments by Casteel (5) on the turtle (*Chrysemys marginata*) bring out the fact that the animals failed to discriminate between patterns. Four animals learned to discriminate between black and white, while one failed to show improvement in 220 trials. Two learned to discriminate vertical and horizontal lines and two between two series of parallel horizontal lines 8 mm. and 2 mm. in width respectively. One turtle learned to discriminate between two series of parallel vertical lines 8 mm. and 1 mm. wide and then between lines 4 mm. and 2 mm. wide and finally between lines 3 mm. and 2 mm. wide. Although not carefully tested, the retention of such habits was surprisingly good.

Casteel states that the turtle does not learn rapidly. One hundred and eighty-three trials were the average necessary to complete the above habits. From extended experiments (Hopkins) in which monkeys, dogs, rabbits and rats have been used as subjects in discrimination experiments it would appear that the turtle learns rather rapidly. It is not at all unusual for the above animals to require 200-600 trials to perfect similar discriminations.

Victor Bauer (2) defends the view that the visual purple functions in daylight vision as well as in twilight vision. His experiments were carried out upon frogs and rabbits. The retinæ of these animals were exposed to light for varying periods under varying conditions, and the color of the retina was then determined. From his results he finds support for the following general conclusions. When the visual purple is bleached by the action of light, certain products are split off. Some of these products enter into reaction with the nerve substances and stimulate them, while others act upon the secretory epithelium surrounding the retina. — The secretions resulting repair or reconstruct the bleached-out purple. The waste and repair of the visual purple takes place not only in dim twilight but even in strong daylight. This may be shown in the isolated bulb, in which the "Restitutionskraft" of the secretory epithelium is gradually exhausted by removal from the body. If sudden strong illumination is admitted to the eye which has been pre-

viously kept in the dark there is a corresponding rich formation of the bleaching products. The building up process is at first not able to repair the waste. Adaptation follows, and the building up process not only compensates for the waste, but continues until the retina which was bleached under the influence of the strong light again becomes red. There is an upper limit to the speed of the restitution process. If the decomposition is increased overwhelmingly, even the greatest activity on the part of the epithelium fails to restore equilibrium, and the retina remains bleached out. Only a decrease in illumination can restore the purple. After a more complete adaptation the "purpling" processes continue, but with lessened activity. In continued darkness the regeneration processes cease, probably in consequence of the lack of the by-products necessary for their arousal.

Birds. Hess (13) (p. 443) confirms by a new method his former conclusion that light-adapted day birds have an extension in the red end of the spectrum coincident with man's, but that the blue-greens, blues and violets have low stimulating value. The explanation of this is to be found in the reddish-yellow oil globules which are to be found in the retina of birds. These absorb the short but admit the long rays. It will be remembered that he in his earlier paper maintained the view that the hen has visual qualities similar to those of the human being, but that due to the presence of the oil globules there are certain differences in behavior. All these differences between hen, and man with normal vision, are smaller than between the hen and the totally color-blind or red-green blind man. I quote his own words (p. 445) on the coloring of the rice kernels for tests on the color blindness of the hen. I am in some doubt as to his meaning, or if I get his meaning, of the possibility of obtaining any such color equations: "Um Hühner nach dem Prinzip der Seebeck-Holmgren'schen Wollprobe mit farbigem Futter zu untersuchen, färbte ich grössere Mengen von Reiskörnern mit verschiedenen Pigmenten so, dass mir insbesondere gelblichrote, angenähert rein rote und bläulichrote, sowie gelblichgrüne, angenähert rein grüne und bläulichgrüne Körner teils in schon freien, teils in mehr oder weniger stark mit Weiss, Grau oder Schwarz verhüllten Farben, ferner gelblichgraue, rein

graue und bläulichgraue Körner reichlich zur Verfügung standen." (P. 445.)

Upon a dead-black table cloth 15 by 39 cm. in diameter he lightly fastened yellow-red grains and between these strewed the different greens and greys. On the second day the hen avoided not only the yellow-red grains, but also the red grains and the bluish red, and pecked only at the greys and greens. This was also the case when he strewed red grains among the greens and the greys (although in this case the red grains were no longer fastened down). With astounding quickness and sureness the animal pecked all the green and grey grains lying between the red grains. If there were only a few of these at hand, it hunted all over the entire cloth between the red grains so that after several seconds only the red ones remained untouched. If he brought such a hen into the dark room to a row of white rice grains, strewed upon a black background, which were not fastened down, and colored these by means of the spectrum, she here likewise left the red and yellow-red grains untouched.

He now laid before a so-called red-green blind person (relatively yellow sighted red-green blind) the differently colored yellow-red and blue-red rice grains and let him choose out of the pile the grains which seemed alike to him. This subject put yellow-green with yellow-red, pale blue with bluish-red. The differently colored grains which the hen had differentiated with such sureness were similar or alike to the red-green blind subject.

A hen which he had taught to avoid the red grains was fed on a black cloth upon which the green grains were fastened down while the red, etc., were scattered loosely. After a short time she no longer took the green grains when these were loosely strewn among the others, but she did take the red ones. In the spectrum she picked the grains lying in the red end as far as they were visible to the normal human eye.

Only for one with the visual qualities of the normal human eye have the different red grains the common characteristic of prevailing redness. He concludes that the possibility of a red-green blindness in the hens experimented upon is excluded, and greater strength is given to his contention that their visual qualities in this respect are similar to or the same as a normal man's.

Breed's (4) paper is concerned more with the modifiability of reactions than with the function of vision as such. Nevertheless experiments were made upon the color, form and size perception of the chick. The evidence for color vision, while obtained incidentally, is believed by the author to support the view that color quality as well as intensity is a determining factor in the chick's response. The chicks seem to be able to respond selectively to one of two objects of different size. The form tests gave purely negative results. In a note on page 57 the author states, however, that a chick acquired the circle-square habit when the experiments were conducted in the dark room. One interesting methodological point is brought out in Breed's work. Chicks will peck in the dark. The work of Hess and of Katz and Révész on vision in the chick is based upon the assumption that the chick will not peck at what it cannot see. The work which the reviewer has carried out upon the limits of the spectrum in chicks this summer wholly confirms Breed's findings in this respect.

Mammals. Minkowski (17) reports in a long and closely articulated paper the results of extended tests upon the localization of the visual centers in the dog. The methods of testing the visual field in normal dogs and of locating the visual defects in the dogs after cortical operation are described as follows. The dog sat with one eye securely bandaged. A piece of meat was then held by a slender rod or with forceps before the other eye at a distance of about 10 cm. This gave a reasonably steady fixation. A perimeter was then drawn forward in such a position that the bit of food occupied its center. A second bit of food was then drawn along one arm of the perimeter until the dog noticed the food and snapped at it. By rotating the perimeter in the usual way the following field was mapped out:

Upper vertical.....	60°-65°
Lower vertical.....	50°-55°
Outer horizontal.....	80°-90°
Inner horizontal.....	30°-35°

The "Kreisleitungsmethode" was employed in a supplementary way. This consisted in moving the bit of food before both eyes of the dog in circles so that the image had to fall at some time upon the upper, lower, inner and outer portions of the retina.

The normal dog follows the food in all directions with pronounced movements of the eyes and muzzle. But where there are marked deficiencies in vision, as in the lower half of the *campus oculi sinistri*, the definite following movements suddenly cease, but begin again when the food is brought within the visual field. At the moment of disappearance, seeking movements of the eyes and muzzle may be noticed. This method gives quick orientation where the deficiencies brought about by cortical extirpation are great. The third auxiliary method he calls the "Auseinanderführungsmethode." Two bits of food are first held above the dog's nose and are then drawn apart in all directions; sometimes both are drawn apart simultaneously, while at others one remains fixed and the other is moved away. (At least so I understand "—dass zwei Nahrungsstücke zuerst über der Nase gehalten und dann verschiedenen Richtungen einzeln oder gleichzeitig auseinander geführt werden").

For the results of the experiments on extirpation of the cortical areas and for the anatomical findings the original paper must be consulted.

AUDITION

Fish. Parker (20) finds that the noise of motor boats is extremely faint under water and has almost no influence upon the movements of fishes engaged in feeding. Single explosive sounds like that of the report of a gun are likely to startle the fish and cause a temporary cessation of feeding.

Some tests made by Dr. A. G. Mayer, Dr. Goldfarb and the reviewer in Tortugas during the past summer on the distance at which sounds produced under water may be detected by a person with head and body immersed do not bear out Parker's contention that sounds heard under water are extremely faint. Dr. Mayer tapped two pieces of coral together under water while Dr. Goldfarb and the reviewer swam away. Up to a distance of approximately 100 yards the faint sound made in the above manner was distinctly heard by both observers with head and body immersed. At this distance Dr. Mayer tapped the two pieces of coral together in the air. They were clearly audible to the observers with heads in the air, but unfortunately we did not try the experiment of giving the sound in the air with the observers' heads immersed.

In Parker's work no mention is made of the possibility of

vision being responsible even for the slight responses he obtained. In the opening sentences of the present paper he says that the fish can feel sounds through the *skin, lateral line organs* and through the ears proper. One of the strong criticisms urged against all of Parker's auditory work by certain German reviewers is that he does not exclude the possibility of response through vision (*i.e.*, visual response to actual wave motions produced by the sounding body). In the present paper, although he cites the work of Hunter (1782) on the responses of fishes to the noise produced by the discharge of fowling pieces, he does not consider the work of Bernoulli (*Zur Frage des Hörvermögens der Fische*, Arch. f. d. ges. Physiol., **134**, 633-644. See review of 1910 literature in this journal, Vol. 1, p. 436), who made similar experiments and arrived at similar conclusions.

Mammals. Shepherd (24) finds that the raccoon learns to respond to its own name and to other articulate sounds. Confusion words were not reacted to. Variations in the pitch of the voice and in the timbre of the voice did not cause failure to discriminate. This work seems to the reviewer merely indicative; in no sense can we say on the basis of such tests that Shepherd's conclusion is justified. The simplest and most fundamental precaution was neglected,—that of being out of sight of the animal during the experiments.

OLFACTION

Fish. Parker (19) tested the ability of *Fundulus* to discriminate between packets of cotton cloth containing dogfish meat and others not containing food. The packets without meat were occasionally approached and seized, but soon dropped. The killifish, in contrast with the catfish, used its eyes as well as its chemical senses in seeking food.

The olfactory nerves were then cut in several animals. Twenty-four hours after the operation the fish were fully active and took food. When tested with the food packets they nibbled at both in a way that made it impossible for the uninformed observer to distinguish one packet from the other. Since the operation of cutting the olfactory nerves was somewhat severe, Parker tested the effect of closing the anterior olfactory apertures by stitches of fine silk. Again discrimination between the

packets was lost. It was restored when the stitches were removed. In cases where the stitches were taken, but where the threads were not drawn up and tied so as to close the aperture, discrimination was not lost. Parker concludes that *Fundulus heteroclitus* uses its olfactory apparatus as an organ with which to scent its food; "i.e., its olfactory apparatus is a chemical distance-receptor of very considerable importance in its daily activities."¹

Sheldon's (23) work on Selachians is in harmony with that of Parker. When a crab is placed in a pool containing dogfish a few minutes are necessary for diffusion to take place. The dogfish which first happens to swim within three or four feet of the crab turns suddenly as if startled, and swims about now eagerly alert and searches for the food. When within three or four inches of the crab it suddenly seizes it and makes off rapidly. Very little use of vision is noted. The food packet method was tried with convincing results. Packets containing stones were not touched, while those containing crabs were always seized. Packets saturated with the juice of a crab and weighted with a stone were likewise seized. When the nasal passages are closed with cotton wadding coated with vaseline, the fish do not respond to the food stimulus. The wadding produces some disturbance, but this factor was sufficiently controlled by testing fish with one aperture closed. From one to two days after the removal of the plugs fish so treated responded normally again.

The general conclusion is that Selachians find their food almost exclusively by a sense of smell which is comparable to that possessed by terrestrial vertebrates.

Birds. Strong (26) takes up the vexed problem of smell in birds from the standpoint of both morphology and behavior. His study of the anatomical features of the olfactory organs in birds leads him to agree with Edinger, viz., that one ought to expect to find evidence of a sense of smell. There is a great variation in the size of the olfactory structures in the different

¹ Since neither Parker nor Sheldon mentions the previous work of Baglioni (Baglioni, S., Contributions expérimentales à la physiologie du sens olfactif et du sens tactile des animaux marins., *Archiv. Ital. de Biol.*, 1909, **52**, 225-230), I cannot help calling attention to the fact that this investigator, on the basis of tests upon the octopus and blind fish (Balistes), urges that these marine forms possess such a chemical sense, and on the question as to whether it should be called smell or taste comes out strongly in favor of calling it smell, since from the standpoint of reaction it is a distance-receptor.

species. Certain of the birds (*Dromaeus* and *Fulmarus*) have relatively larger olfactory apparatus than man. There is some evidence (according to his interpretation) in the case of the higher birds that the development of keen vision is being accompanied by a degeneration of the olfactory sense. On pp. 642 and 643 one finds a table of comparative measurements of the different parts of the olfactory structure, and on 659 and 661 excellent drawings of the olfactory organs and of their external relations to the brain as a whole.

On the behavior side, Strong presents some results obtained from experiments upon a maze which offered the possibility of association between a given odor and food. The birds never learned to find their food with perfect accuracy during a series of tests given twice daily and extending over a period of nine months. During this time, however, there was an increase in the number of correct responses to the oil of bergamot. Strong's field observations upon the turkey vulture in Florida were not productive of convincing results.

No control experiments upon birds with olfactory bulbs removed were made. It seems probable that Strong's tests could have been carried out much more quickly and easily if the two "choice" method instead of the four had been followed.

EXPERIMENTAL AND OBSERVATIONAL STUDY OF INSTINCTS

Fish. Sumner (27) in a rather loosely articulated paper gives the results of his highly interesting experiments upon the adjustment of the flatfish to its background. Pages 467-471 give a very clear summary. In brief, Sumner finds that flounders become very pale upon white backgrounds and very dark upon black ones. These adaptive changes usually lie within the black-white series. In mixed backgrounds composed of sand and gravel the fish respond by assuming definite patterns oftentimes in distinct harmony with those of the background. Backgrounds made up of areas of black and white call forth greater contrasts in the skin patterns than those of sand and gravel. Squares, crossbands, circles, etc., were never copied in any true sense. Adaptation is most complete upon backgrounds forming a part of the natural habitat of the animal, but it is not limited to such conditions. There is a wide range of adaptability.

The markings of the underlying surface were most effective in calling forth the changes. The markings on the vertical walls of the tank although effective were less important, while the overhead environment exerted little or no influence.

The fish seems to make no direct comparison between its body and the background. Adaptive changes occur when the fish is buried in the sand and when its body (eyes excepted) is covered with a cloth.

The changes in some way are conditioned upon optical processes, since at least one eye must function normally if the changes are to occur. If blinded when in the dark condition, the fish ordinarily remained dark; if blinded in the pale condition, they remained in that state for about a day and then reverted to a darker condition.

The author is conservative in his statements throughout and rests content largely with stating his findings. The photographs are excellent and on the whole convincing. The reviewer feels that the patterns shown in the photographs could have been somewhat better evaluated if Sumner had photographed along with the flatfish some fish rather constant in its color tone and pattern, and one which does not undergo such adaptive changes. In many cases, though, the author has photographed the flatfish in pairs in such a way as to leave no room for questioning the pronounced effect upon the pattern of the fish of changes in the backgrounds.

Werner (28) calls attention to the sleeping attitudes of several species of fishes (*Amiurus nebulosus*, *Misgurnus fossilis* and *Cobitis talnia*). Sleep is needed by all members of the groups particularly studied (*Silurus glanis* and *Cobitis barbatula*) but the bodily attitudes taken are quite different even in the nearly related races. In general there is a complete cessation of activity, a certain chosen bodily attitude, and almost complete stoppage of breathing. Very light contact is sufficient to reawaken the fish.

Romeis (21) takes up in detail the peculiar movements of the Maulbrüter (*Paratilapia multicolor*) in seeking during the breeding season a resting place under the leaves of certain water plants. When in the neighborhood of the thickly matted plant leaves, it interrupts for some seconds the lively play of its fins, swims slowly here and there, and when a suitable place

is found it folds its fins, assumes a characteristic position (ganz schräg auf seine Breitseite gelagert) and remains in this attitude from one-half to two hours. Only the regular but slow movements of the gill cover show that life is present. Romeis doubts whether the above described form of sleep is very profound, since the near approach of any object, or noises, causes the fish to take flight immediately. The author sees in this activity a mechanism which is economical with respect to metabolism. It should be designated generally by "Ausruhestellung."

At night the behavior is different; the fish ordinarily sinks to the bottom of the container and rests on the ventral surface. Fin movements cease. It seems to be genuinely asleep, since light in moderate intensities and noises do not disturb it.

Amphibians. Mulder (18) finds that the speed of the rotation reflex is directly proportional to the amount of the stimulus. The relation is not logarithmic as is the case with sensations.

Birds. Breed (4) finds that the drinking instinct does not have to be supplemented by imitation, accident, intelligence, instruction, etc., in order to act. The pecking response as a whole is very imperfect at birth. For purposes of observation the response is subdivided into three separate reactions: striking, seizing and swallowing. The amount of daily improvement of the act as a whole and of its separate parts was measured up to the 25th day. Pecking improved in accuracy rapidly during the first two days. On the third day efficiency is placed at 29.29 on a scale of 50, 40.10 on the eleventh day and never higher than 42.57 for the rest of the time of observation. Social influence exerted little effect in improving accuracy.

On page 40 Breed raises the very interesting question of the relation of habit to instinct. Although in pecking there is improvement with practice, the question remains whether the increase in accuracy is dependent upon practice, or whether it is the natural functional correlate of structural maturation. The question might be answered experimentally, it would appear, by forced feeding of a group of chicks for the first week and then making a comparison of the accuracy of pecking with that of a group brought up in the normal way. Since the nervous system resists starvation well, it is doubtful if a few days of slight underfeeding would check the normal rate of the development of the sensory-motor arcs.

Craig (10) shows that stimulation of a female dove by the male without copulation was followed by oviposition. "The present paper goes to show that the stimulus to the whole process of egg development and laying is a psychic (neural) stimulus not dependent upon the introduction of sperm." (P. 305.)

Chappellier's (6) paper is a brief report upon a systematic study of the sex organs and sex life of hybrid birds. He discusses the apparent sex indifference in female hybrids obtained from crossing canaries and goldfinches. He mated one of these females with a canary. Nest-building began shortly after mating. The process of nest construction was desultory and lasted through the egg-laying period. The first egg was laid more than two months after mating. During 92 days she laid 16 eggs in a very irregular fashion and ate each of them in turn within one or two days after laying it. Although mated with an ardent male, she was entirely indifferent to him. This passivity in hybrid females is connected with a rudimentary condition of the ovaries, which are represented by three or four small formless masses.

Herrick (12) devotes nearly 100 pages to the nest structures and the activity of nest-building in birds. The series of papers is very comprehensive. He treats of the function of the nest, the classification of nests on the basis of behavior, analysis of increment nests, variations in nests of certain birds, nidification, intelligence in nest-building and the origin of the instincts of incubation and nidification. The discussion of nidification is based chiefly upon the writer's field observations of behavior in nest-building. The author is conservative in his discussion of the presence of intelligence in nest-building: "Instinct furnishes the springs of action in birds." These are exceedingly complex and in a high degree adaptable. This innate equipment takes the place in a large measure of mind or intelligence. He finds evidence of a wide group of associations between sense impressions and motor impulses. Habits of approaching and leaving the nest are quickly formed. Apparently one finds occasional adjustment of means to end where difficulties arise.

In regard to the origin of instincts of incubation and nidification, Herrick reaffirms his former position: the instinct to hide supplemented by that of guarding the eggs is responsible for the later instinct of incubation where guarding with concealment

is effected in the same act. Why the instinct of incubation needs to have its "origin" accounted for any more than that of the hundred other instincts birds possess is not clear.

Craig (8, 9) gives the best description we have of the intimate family life of the mourning dove. He describes the various emotional states of the birds, such as those expressive of enmity, fear, alarm, and gives their various calls and cries in musical notation. The second part of the first paper (*The Expressional Life History*) treats of the breeding habits of the mourning dove. The breeding cycle of a pair of captive birds taken from Professor Whitman's aviary is described in detail.

His opportunity for making original observations upon the passenger pigeon was more limited. The species is now apparently extinct, and for this reason his rather brief notes upon the life history of *Ectopistes* are of especial interest. This species possessed characteristic voice, gesture and social life. It was comparatively awkward upon the ground and was therefore naturally less given to strutting and charging than other pigeons. Its voice was strident and lacking in musical notes. While the bird was quarrelsome, it was poorly equipped for fighting. Its courting was characterized by great roughness.

ORIENTATION

Mammals. V. Máday (16) discusses the problem of orientation in the horse. The origin of the impulse to home in this animal is supposed by the author to have been carried over from its wild ancestors. The *Heimweh* of the domestic horse has its origin in the *Wandertrieb* of its wild progenitors. This *Heimweh* is probably the most compelling impulse possessed by the horse.

Tests of homing were made by riding to distant points and then releasing the reins, thus allowing the horse to return by its own unaided efforts. The author tells us that he did not direct the horse except when gross errors were made! Surely the involuntary attitudes of the rider may have played a part both in the successes and the failures of the animal! When the horse reached the designated spot he was given the reins. The animal remained still for from one to two minutes, then started forward, then turned in the arc of a circle 10-15 m. in diameter and for a short distance retraced the outgoing course,

finally choosing its own course so as to eliminate the detours made on the journey out. The journey was not made without error. Improvement by practice was noted. We are not given the details of the journeys—*i.e.*, distance traversed, times on successive trips, etc., nor the previous training of the horse. Several pages are devoted to discussion of theories, the senses of the horse, and the author's conclusions. In brief the latter are as follows.

Orientation is not a physiological reflex but a psychical process. All the senses play a rôle with the exception of taste. In the order of their importance in orientation the senses are listed as follows: smell, hearing, touch and sight. Direction, intensity and temperature of winds are important factors. It is curious that sight appears last in the list. He gives no experimental grounding for this particular hierarchy of the senses. From the author's note it appears that mistakes are often made when orientation is attempted through sight. In all of the higher animals orientation is a complex process involving both conscious and unconscious factors. The unconscious factor in orientation according to the author consists chiefly in a *Richtungsgefühl*. His discussion at this point is so naive and out of place in a journal with the standing of the *Zeitschrift für angewandte Psychologie* that the reviewer feels compelled to quote it in full: "Welcher Art ist die bei der Orientierung geleistete unbewusste psychische Arbeit? Antwort: sie besteht hauptsächlich in dem sog. Richtungsgefühle."

Welche physiologischen Faktoren (Sinnesorgane) dienen dem Richtungsgefühle zur Unterlage und welcher Art sind die dabei entstehenden Empfindungen und Vorstellungen? Antwort: von verschiedenen Organen (hauptsächlich dem Ohrlabyrinth) kommen Lageempfindungen; auf diesen baut die Seele ihre Raumvorstellungen auf." (P. 85). In concrete cases, according to V. Máday, this *Richtungsgefühl* comes about through the unconscious registration of "detours" (Darwin). It is evident that the author was not really prepared, either from the standpoint of his familiarity with psychological theory or from his experimental equipment, to undertake such a problem. It is to be regretted that the journal in which the article appears will continue to give space to the reports of such unsatisfactory experimental work and to such long and rambling discussions

as are to be found in this article and in the one by Franken, on the instincts and intelligence of the dog, reviewed last year in the *Journal of Animal Behavior*.

IMITATION

Mammals. Shepherd (25) gives some experiments upon imitation in raccoons. One of the animals had learned by the trial and error method to walk up an inclined plane of poultry netting 1.5 m. in length and 25 cm. wide to a box where food could be obtained. This animal was used as the "imitatee." Three other animals tested separately were allowed to watch the imitatee perform this feat. Since these animals repeatedly failed to profit by watching the trained animal perform the act, Shepherd concludes that "inferential" imitation does not form a part of the raccoon's mental equipment.

HABIT FORMATION

Amphibians. Schaeffer (22) finds that the three species of frogs studied (*R. clamata*, *R. sylvatica*, *R. virescens*) learned to avoid disagreeable objects, such as hairy caterpillars, in from four to seven trials. These habits persisted for at least ten days. Under the influence of punishment by the electric shock, *R. clamata* learned to avoid earthworms treated with chemicals in two trials.

Those habits which are intimately connected with obtaining food are acquired by these animals in a time which is directly comparable with the acquisition of similar habits in higher forms, e.g., chick, tern, monkey, etc. The frog has been placed low in the scale of intelligence by other investigators. This is due to the fact that the problems presented it hitherto have called into play relatively few of its hereditary mechanisms. Two or three pages are devoted to the fruitless task of discussing the psychic processes in the frog.

Birds. Hunter (15) finds that the pigeon forms maze habits as readily as other birds, but not so readily as the rat and the squirrel. The maze habits are perfectly retained for four weeks. Visual and kinaesthetic cues are used in the learning process. Kinaesthesia does not play so important a rôle in the mental life of the pigeon as in that of the rodents. Although no especial tests were made upon audition, Hunter is in agreement with

Rouse that pigeons are very sensitive to sounds. From the tests with the rotated maze Hunter draws the conclusion that pigeons seem capable of changing their system of cues in response to the varying demands of a new situation. It is unfortunate that Hunter could not carry out these rotation experiments in an apparatus which permitted of the simultaneous rotation of the background.

Cole (7) continued the work of Yerkes and Dodson on the relation of the strength of the stimulus (punishment by electric shock) to rapidity of habit formation when the discrimination is (1) easy, (2) medium, (3) difficult. Chicks (barred Plymouth Rocks) were used as the subjects. The relative brightness of the stimulus plates in the three sets of tests is given as follows:

(1) Easy discrimination.....	0: 8.9
(2) Medium " 	1: 13.7
(3) Difficult " 	1: 5.1

Punishment was administered by grills connected with a calibrated inductorium. It was found that the number of trials necessary to form the habit of choosing the darker of the two screens when the difference in illumination is great decreases with the stimulus. This law holds, for discriminations of medium difficulty, only for the lower intensities of the stimulus. It holds likewise for difficult discriminations if the records of the chicks which succeeded in making it are alone considered. "If, however, we consider only the chicks which fail, the optimal stimulus recedes once more to a point nearer the threshold of stimulation than in the case of medium discrimination."

In the present state of the subject it is very doubtful if such results can be wholly relied upon. Quantitative experiments designed to isolate the effect of punishment are full of pitfalls. The effect is masked by practice effects, individual variation in animals, variations from day to day in the same animal, and by the almost insuperable difficulty of keeping an inductorium running for long periods of time without introducing serious errors due to the oxidation of the contacts through sparking, heating, etc. No condenser was connected across the terminals. Apart from the difficulties inherent in the method, Cole certainly worked with extreme care. The only criticism which can be

urged in the conduct of the work was the *failure to carry out control tests without punishment in each of the three sets of experiments.*

Mammals. Hamilton's (11) paper voices a protest against the detailed and narrow experimental studies in behavior. His interest is not centered in the acquisition of definite habits, but rather in the reaction tendencies displayed by the animal when face to face with a situation for which it has no appropriate instinct, no opportunity for imitation, and no rational equipment. He states his problem as follows: "What, if any, are the qualitative differences of reaction tendency that account for the fact that some mammals learn slowly, and with many errors, to meet situations which their fellows of superior age or race learn to meet quickly and with few errors?" In order to gain insight into the different reaction tendencies of his subjects, he gives them a problem in which it is required to obtain exit from a room containing five doors. One of the doors is for entrance only. Each of the remaining four doors may give exit but only one gives exit in any given trial. The subject has to find which door gives exit. He must push against it: if he finds it locked he must try another. It will be seen at once that the type of problem is quite new.

The subjects chosen were human beings, monkeys, dogs, cats and horses, of different ages. From the varying behavior of these subjects he succeeds in isolating what he calls various types of reaction:

Type A: "The reaction must include a single, definite effort to open each of the three inferentially possible doors, and must not include an effort to open the inferentially impossible door." (The impossible door varied from trial to trial). This is *the rational inference type*: apparent only in the eight normal adult subjects.

Type B: This reaction involves trying all four doors but once each and in an irregular order: *The unmodified searching tendency*. It is exhibited by one defective and by all of the animals in the following order with respect to frequency of its display: monkeys, dogs, cats, horses.

Type C: Striking once, each of the four doors in succession, starting either left or right. (This can occur only when either door 1 or door 4 is locked). *The tendency to adopt stereotyped modes of searching*: especially exhibited by monkeys.

Type D: This involves the error of making more than one separate continuous effort to open a given door during the same trial, but always with an interruption of such repetitions of activity by an interval of effort to open one or more of the other doors. *The searching tendency modified by recrudescence of motor impulses*: regularly increases as we descend the phyletic scale.

Type E: Includes several different modes of behavior which have a common objective characteristic, *viz.*, automatism. This is a relatively implastic and unadaptive mode of behavior. *The tendency towards perseveration of active impulses and inhibitions*: increases regularly when both phylogenetic and ontogenetic scales are descended.

Bogardus and Henke (3) studied in the rat the rôle played by head and nose contact in *learning* the maze. The vibrissae were cut off before experimentation began in order to facilitate the observation of the actual head and nose contacts made at the corners of the maze. It was found that the percentage of corners touched is high at first, and then gradually decreases as the maze is learned. There is a high correlation between the number of contacts and the number of errors made, and between the increase and decrease of time and the number of contacts. When the maze is learned, contact at corners is no longer necessary. Blind rats (previously trained on another maze) were then required to learn the maze used in the first set of experiments. The results obtained were similar to the above, and add weight to the contact theory of acquiring kinaesthetic and organic cues. This general conclusion is further strengthened by experiments in which the pathways of the maze were altered in various ways.

Hicks (14) gives a timely and exceedingly valuable discussion of the relative values of the different curves of learning. The author holds that the distance curve is a better representative of the progress towards automatic accuracy than the error curve. It, however, is impracticable from the standpoint of recording and manipulating the data. The prevalent practice of omitting all total and partial returns from the error record, and of making no attempt to evaluate varying degrees of error, gives a curve which is not only *worthless* but *false*. It is suggested that an error curve which includes returns, and which is constructed on

the basis of regarding a small segment of the maze as the unit of error, constitutes a practicable substitute for the excellencies of the total distance curve. Time is the best single criterion.

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THORNDIKE'S "ANIMAL INTELLIGENCE"¹

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Professor Thorndike's series of experimental papers, republished in this volume, constitute a conspicuous landmark in the development of comparative psychology. A review, thirteen years after the appearance of the first paper, can pretend to be little else than an appreciation in the light of subsequent progress. (1) The existence of the trial and error method of learning was demonstrated in fishes, chicks, cats, dogs, and monkeys. The random activities are an expression of the animal's innate and acquired nature, and any problem must be adapted to this nature. Motives of hunger, release from confinement, the social instinct, and preference for shade were utilized. Subsequent work has extended these tests and results practically throughout the zoological scale. (2) The analysis of imitation is excellent. The methods are those in use today. The results were negative for all animals studied. The conclusions as to inferential imitation have been substantiated by subsequent work. The author admits the possibility of other forms of imitation, and his statement that no influence upon conduct was evident in his tests must be interpreted in the light of the fact that his interest in inferential imitation would lead him to overlook slight influences of an instinctive and social nature. The tests were not always sufficiently controlled, but this defect was explicitly recognized, a statement which can not be made of some subsequent work. (3) The experiments on tuition have not stood the test of repetition and criticism. Again, the author was interested in the influence of ideas, and in this respect his conclusions seem valid. (4) Transference of training to similar problems was noted, but not much of the phenomenon is understood at present. The interpretation of the doctrine of receipts is probably the conventional one. (5) Difference of retentive ability was studied. Such tests have been duplicated,

¹ Thorndike, Edward L. *Animal Intelligence*. New York, The Macmillan Company, 1911, pp. viii+297. This is the third volume of the "Animal Behavior Series."

but practically nothing adequate is known of the retentive function as yet. (6) The discrimination experiments were poorly controlled. It is within this field that subsequent work has made its greatest progress. He used two methods, neither of which has been followed. In one a reaction to a given object is inculcated and then similar objects are interpolated in the series of tests. The second, so far as the distance senses are concerned, is much superior to those in use at present. A visual object "a" was placed against a defined background "b," and the animal was forced to discriminate "a" from "b." Recent unpublished work from this laboratory has demonstrated that when two spatially distinct objects are placed against an unknown background, as is commonly the case, one of the objects may be ignored. (7) The study of the instincts of chicks is excellent and most of the conclusions are yet valid. (8) The significance for intelligence of a development in motor capacity was strongly emphasized, a neglected topic in contemporaneous thought. (9) Animal learning was regarded as a process of association on the sensory-motor level. Animals may and probably do have ideas, but such ideas were not effectively present in their experimental behavior. So far as the reviewer is concerned, this conclusion is still valid, as no experiments yet published are convincing as to the presence of ideas.

Such a summary in comparison with the present status of the science reveals the fact that these studies represent no inconsiderable achievement. Some new problems have since been attacked, *e.g.*, the relative values of the different senses in learning, etc.; the old problems and technique have been developed, but subsequent work has consisted to a large extent in a similar extended exploration of the animal scale. The author's success seems to be due primarily to his acute and thorough analysis of the human processes involved and to his keen appreciation of the logic of experimental procedure. While he robbed animals of their assumed ideational powers, yet he bridged the gap by his insistence upon the prevalence of the trial and error method of learning in the human mind.

Contemporaneous criticism was severe. The strictures as to the use of "utter hunger," an unfortunate expression, were unjustified so far as fact was concerned. Apology is made for the irritating dogmatic tone often displayed, and for the ten-

dency to read severe advice to cognate disciplines. However, the contemporaneous attitude toward ideational interpretation of isolated cases of behavior *was* settled "once and for all" by these papers. The tendency to seek in experimentation an excuse to express views on the whole field of human and comparative psychology characterized other papers of this period, and in fact such a tendency is not without value in the development of any new field. Some interpretative positions were unfounded; the ideational significance of retentive permanence and of a sudden drop in the learning curve are doubtful propositions.

Two chapters are new. The first concerns the province of the science. It maintains the thesis that comparative psychology may deal with behavior for its own sake. Criticism is here futile, for we enter the realm of personal opinion. A better exposition of the validity of the objective method is difficult to find, but perhaps this statement is too much colored by the reviewer's bias. The chapter on the laws and hypotheses of behavior is one of the most important in the book, inasmuch as it expresses the author's mature opinion formed in the light of a decade of subsequent experimentation. The reviewer finds, however, more opportunity for dissent and criticism than in the earlier work. A few points may be noted.

(1) The law of causation holds sway; the behavior of any organism is wholly determined by the stimulus and the nature of the organism. This conception is emphasized because, it is asserted, two popular doctrines (in the sense of widely accepted, I presume) exist in defiance of it. The first is the doctrine that behavior is random. I deny that the term necessarily implies a meaning antagonistic to the above principle. A similar objection might also be made on just as good grounds to the phrase "accidental success" which is so liberally sprinkled throughout the book. That the term "random" can be employed without doing violence to the principle is evident from the fact that the author himself uses it twice (p. 255). If, as implied, any great number of writers actually do employ the term in the objectionable sense, I venture to suggest that a few names be specified. The second is the doctrine "that the need for a certain behavior helps to create it." This term can also be used without violating the principle. A "need" may represent the presence of a persistent irritating stimulus or the absence of a

customary stimulus, resulting in behavior of the trial and error sort which finally leads to accidental relief. Or, needs may be regarded as a constituent part of an animal's nature. On neither hypothesis does the concept of need violate the enunciated principle. Again, the specification of the names of a few of those who do use the term in the tabooed sense would satisfy one of the reviewer's needs. A suspicion is aroused that the author is here strenuously belaboring a straw man of his own manufacture.

(2) The learning process is explained under two main laws (effect and exercise) and two secondary laws (assimilation and partial activity). In the main the reviewer sympathizes with this formulation, but finds occasion for a few minor criticisms.

(a) I doubt their comprehensiveness. I am not ready to admit that selection of acts according to their affective (pleasure-pain) consequences is the only principle of selection. The law of exercise is to some extent the application to animal acquisitions of the secondary laws of association. The law of exercise is inadequate in the field of animal learning, just as the secondary laws of association are inadequate to give a complete and comprehensive account of all the known conditions of human learning, *e.g.*, the phenomenon of the influence of the temporal distribution of trials or effort. My feeling is that the gradual selection and automatic growth of an act is too complex a matter and too little understood at present in many of its phases to be embraced adequately under the principles enunciated. Learning is conceived in too simple a manner. On page 280 is found the statement that the evolution of behavior is a simple matter; it reduces to differences of concrete particular connections and to differences in learning ability. This may be true, but I have found that the analysis of what constitutes degrees of learning ability is anything but a simple matter. (b) The law of effect states that in a series of random acts the selection of the proper or teleological act is made on the basis of the satisfying and dissatisfying consequences of those acts. What is satisfying or annoying can often be inferred on the basis of analogy with the human, *e.g.*, food or physical pain due to electric shock. In case this method fails to give a clue, we need some objective criteria. Satisfying conditions, we are told, are those which the animal tends to attain and preserve, and the annoying are those which are avoided and abandoned

(p. 245). In other words, we have to formulate a principle to explain the process of elimination and selection in a series of acts directed toward the solution of some problem, and we are told that the animal neglects, eliminates, avoids and rejects those acts which it avoids and abandons, and preserves and selects that act which it attains or preserves. This sounds suspiciously like the simplicity of alleged feminine logic which asserts that a thing is so because it is so. (c) That acts are selected according to their affective consequences may be admitted. Any explanation in terms of neural mechanics is a difficult problem, but one that should be attempted. A solution that fails to give the detailed mechanics of the process fails to simplify matters. I do not see that the principle of "utility to the neurones," which may be correct for all I know, gives this needed touch of simplification to the process.

(3) The doctrine that an idea of a response in and of itself is unable to produce that response already possesses a history of acrimonious discussion in the field of human psychology. The reviewer possesses no set of fixed ideas upon the subject, and the proposition hardly lends itself to an adequate critique in a short paragraph. It may not be amiss to state briefly what, I conceive, would be the answer of some of Thorndike's antagonists to this proposition. The author contends that the idea itself can not produce the act. The idea can do so only when a "bond of association" between the idea and the act has been established in past experience. The antagonists would assent to this latter proposition, and assert that that is exactly the reason why an idea of an act always does tend to eventuate into the act, that ideas of acts always do possess these "bonds" with the acts because an idea of an act can arise only from past experiences with that act. They would assert that it is this bond with a particular act that makes the idea an idea of *that particular act* rather than an idea of *something else*. In other words, they would assert that "this idea of an act without a bond" is a mythical entity of Thorndike's creation which no more exists than does the Jack of Spades. Such a mythical idea might for the sake of the argument be called an idea, but it could not properly be termed an idea of anything. While all ideas of acts do have bonds with those acts because of past experience, yet there is a sense in which an idea of an act can

produce the act without a *direct* bond. This is the case of the ideational construction or alteration of a new act out of old acts. Suppose we have ideas "a" and "b" of acts "A" and "B" with the given bonds of connection. The situation necessitates the creation of a new act "C" by coördinating A and B in some way. It might be asserted that this coördination may be perfected on the level of their ideational representatives "a" and "b," and, when perfected, the act C would result although no *direct* bond exists between the new idea and the new act. Otherwise, ideas would possess but little value in volitional activities. In fact, as the reviewer read the author's discussion, he began to wonder whether ideas could possess any utility whatsoever in Thorndike's system. The suspicion was engendered that ideas are mere by-products of sensory-motor connections, and that the author could give a smooth account of all the processes involved and of the development of intelligent behavior in both man and beast without the least reference to ideas.

HOLMES'S "THE EVOLUTION OF ANIMAL INTELLIGENCE" ¹

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Professor S. J. Holmes, a biologist whose work is highly esteemed in France, has recently published a very interesting work on comparative psychology, entitled "The Evolution of Animal Intelligence." In order to demonstrate this evolution, Holmes studies a certain number of types, chosen in such a way as to bring into evidence the activities from which intelligence is derived; certain groups of the animal kingdom are left entirely out of account, because they are hardly adapted to furnish useful data towards the solution of the problem which the author has set himself.

From the outset, Holmes clearly shows what his guiding ideas are. The ingenious theory wherein he makes pleasure and pain play an important rôle is already familiar to us: these are the powerful agents of inhibition and reinforcement, and consequently of adaptation and evolution; the development of pleasure-pain reactions constitutes the most important stage in the evolution of "behavior," for the development of intelligence itself is, according to the theory, based on these reactions.

But to speak of pleasure-pain means to raise at once the question of *consciousness* and *sensations* in the lower animals, questions which have already given rise to so much controversy. We have certainly no means of knowing states of consciousness outside of ourselves. Holmes does not conceal this fact from himself, but it does not prevent him from continuing the discussion. The analogies between man and the higher animals are so evident as to make it certain that the latter are conscious of some of their acts. In the case of lower forms, we are reduced to probabilities. Certain writers, among whom the author is mistaken in citing me (for to me there is no objective mark of consciousness), have regarded ability to learn, or associative

¹ Holmes, S. J. *The Evolution of Animal Intelligence*. New York, Henry Holt and Company, 1911, pp. v+296.

memory, as a criterion of consciousness. Romanes and Morgan hesitate to conclude that there is no consciousness where there is no associative memory. According to Holmes, it is probable that all animals which learn are conscious, but such is not necessarily the case; moreover, we must not deny consciousness to animals that cannot learn. But are there such animals? I think not: there are, as Margaret F. Washburn has well shown in her fine book, "The Animal Mind," various ways of learning. Among these ways, one of the most perfect is "associative memory." Now my researches on actinians and the very recent ones of Metalnikow on infusoria show that associative memory functions even in the lower organisms, and is consequently a general property of living matter. We should thus be led to admit that a sort of consciousness accompanies all organic processes, a conclusion calculated to satisfy those who allow no breach of continuity in the sequence of vital manifestations.

Holmes devotes two chapters (II and III) to Reflexes and Tropisms. According to him, the writings of Jacques Loeb, and in particular Loeb's book on heliotropism in animals, by the interesting facts which they have made known, the ingenious experiments which they have suggested, and the general theory to which they have led, have had a considerable and stimulating influence. We must not rest contented with describing the facts of behavior; we must seek to explain them. Holmes then examines the criticism of Jennings to the effect that in certain alleged tropisms there is no definite orientation. He next passes to an examination of the variations in phototropism, and speaks in particular (p. 50) of some unpublished experiments by Michener, according to which chemicals cannot make a reaction negative which was primitively positive. But Anna Drzewina has recently succeeded in producing this result by using a substance, potassium cyanide, which inhibits oxidations; and acids act in the same way when their action is prolonged.

The next chapter (IV) treats of the "Behavior of the Protozoa." The reader has already had an opportunity, in the *Biological Bulletin* for 1907, to become acquainted with the author's very interesting considerations on the rhythmic activity of certain infusoria (*Loxophyllum*). Holmes thus treats this question with especial competence. He recalls at the outset the memory of our regretted Binet, and discusses at length the

possibility of choice in the infusoria. According to Mast, who is here in essentials repeating an opinion of Maupas's (expressed in my "Naissance de l'Intelligence"), the choice is only apparent, and is due, for example, to the fact that the prehensile organ adheres to certain organisms and not to others. But Metchnikow has just shown that if the infusoria do not in general choose their food, they can at least *learn* to choose it.

With Chapter V the discussion on instinct begins. Holmes recalls the fact that I have regarded "instinct" as a word adapted merely to hand down to us certain old notions which flourished before the introduction of experimental analysis in comparative psychology. He himself is a partisan of the conservation of this word. The animal, he justly observes, is not merely a machine which responds to the various influences of the environment: it possesses an innate stock of impulses, which lead it to act in a definitely determined manner, independently of stimulations from the surroundings. From the beginning of its life, we must take account of *internal impulses* (the *Triebe* of the German writers). Instinct represents this innate stock of impulses: to keep the notion of instinct means to show that we do not fail to recognize *the importance of internal states, of internal factors*. In other respects, the activities determined by internal factors do not differ fundamentally from the activities called reflex. The stimuli are internal instead of external.

Holmes speaks of the "marvellous adaptation" of instinct; yet he recognizes that in many cases it is far from being perfect, and he shows us instincts which are in process of perfecting and evolving (Chapter VI).

Two very interesting chapters are VII and VIII, which treat of "Non-intelligent Modifications of Behavior," and of "The Pleasure-pain Theory." According to Holmes, even among the lower organisms there is a sort of auto-regulation of actions, which leads to adapted responses: these responses have contributed to the development of intelligence, which in its turn has had its full expansion when the adaptations have become much more varied through the perfecting of the formation of associations. Many facts bearing on this subject are set forth in a series of paragraphs entitled: "Action of Combined Stimuli," "Diminution of Reaction to Repeated Stimulation," "Different Kinds of Response to a Given Stimulus," "Influence

of Internal Factors on Behavior," "Habits," "Rhythms in Behavior." It was with pleasure that I saw mentioned and discussed some of my own researches, in particular those on the temporal variations of sensibility in *Cerianthus*, and on tidal rhythms. The following appears to me to be a very general law: in proportion as external excitations are repeated or prolonged, sensibility at first increases and later diminishes, the first phase being shorter as the organism is less rich in certain active substances. One gets a glimpse here of the interest which attaches to physico-chemical explanations, which Holmes does not reject, but of which he takes little account, no doubt because they are still a little premature. On the subject of rhythms, I should like to remark that there are strong rhythms and weak rhythms; the latter may be easily masked by the causes actually in operation, and great precautions, which certain authors (Morse in particular) have failed to take, and which I have indicated in my articles (sensibilisator, maintenance of constant illumination and hygrometric state, etc.) are necessary to demonstrate their existence. I shall not revert to the pleasure-pain theory, of which I have spoken above and which is well known to the readers of this review, since it was set forth at length by its author in the *Journal of Comparative Neurology and Psychology* for 1910. With pleasure-pain reactions intelligence came into being. Holmes justly rejects the old opposition of instinct to intelligence: there are already present along with instinct the rudiments of intelligence when the animal profits by experience through the formation of associations; from simple associative memory it is possible to pass through all the intermediate stages to the complicated forms of reasoning. These are the views which I also have maintained in my books, "*La Naissance de l'Intelligence*" and "*La Nouvelle Psychologie Animale*."

In the following chapters (IX to XIII), Holmes seeks to show us the evolution of intelligence; with Bethe, Spaulding, and A. Drzewina, he presents to us the primitive forms of intelligence in crustaceans and molluscs, and discusses the intelligence of insects, lower vertebrates, mammals, and, lastly, the monkeys. In treating of the mammals, he insists on the necessity of experiments: he discusses in particular those of Thorndike, his imitators and pupils. But experiments should be conducted with discrimination, and caution must be observed in drawing

conclusions from them. We must not forget, as certain psychological trainers of animals have done, that "the lion of the desert is quite a different creature from the lion of the circus." Holmes discusses the formation of ideas, reasoning, and imitation in the higher animals, and reports the exploits of the monkey Peter, whom an illustration shows in the act of dining. He brings the book to a close without formulating his conclusions, but they are apparent as one reads it.

Some surprise may be felt that Holmes fails to mention the work of Pawlow's school, which deals with conditioned reflexes where the method of psychic salivation is used. These experiments, which furnished the stimulus for the recent researches of Metalnikow on the infusoria, have the great advantage of helping us to penetrate into the determinism of animal behavior, and making us understand how far such behavior is from being adaptive. In my opinion, Holmes lays too much stress on adaptation, the finality of acts: in most cases this is but a delusion and a snare. Intelligence itself is for us only a very imperfect instrument.

However, Holmes's book is very valuable; its facts are well selected, its ideas interesting and original. Every biologist and philosopher should read it.

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